TP 13475E

IMPACT OF EPA LOCOMOTIVE EMISSIONS STANDARDS ON CANADIAN RAILWAY SECTOR

Prepared for
Transportation Development Centre
Transport Canada

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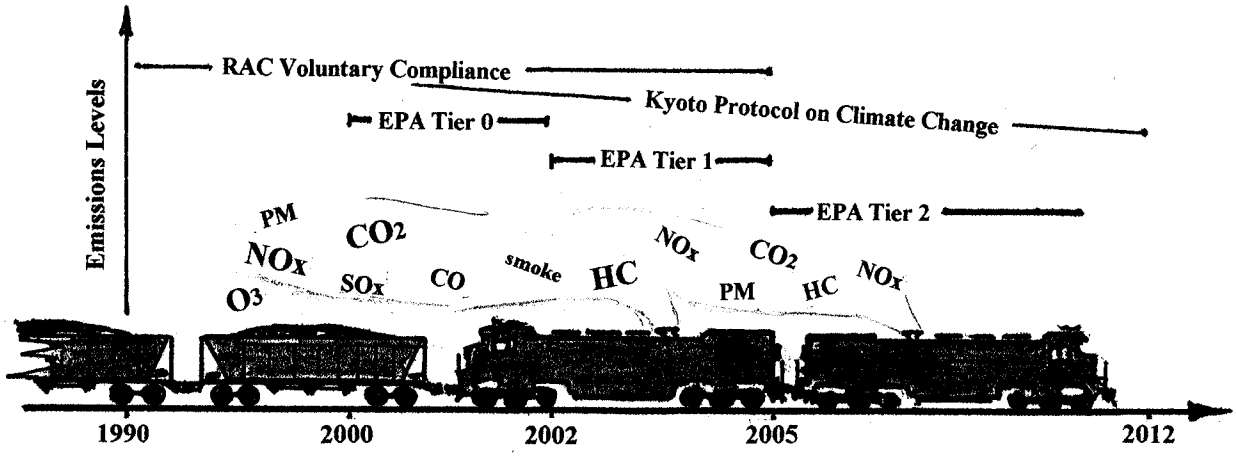

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NOTICES

This report reflects the views of the author and not necessarily those of the Transportation Development Centre.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

Since the report deals with the North American railway sector as a whole, units of measure are a mixture of imperial and metric units (as per current Canadian railway convention) and American units (as per current railway convention in the U.S.A.).

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

This report summarizes the content and implications of the rulemaking promulgated in April 1998 by the U.S. Environmental Protection Agency concerning emissions standards for locomotives and locomotive engines operating in the U.S.A. Its impact on the Canadian railway sector is then examined since no legislated emissions standards currently exist for locomotives operating on Canadian railways; the Canadian railway sector has opted for voluntary monitoring. As the equipment and operating context for the Canadian railways is highly integrated with that of their American counterparts, and the Canadian and American economies are increasingly intertwined, affected constituents of the Canadian railway sector include mainline and regional railways, original equipment manufacturers, re-manufacturers and overhaul facilities, after-service parts suppliers, testing establishments, fuel and lubricant suppliers, environmental agencies and regulators, innovation and research organizations, public advocacy groups, and industry and employee associations. The report provides a discussion and database for possible policy options and strategies regarding emissions from Canadian locomotives.

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16. Résumé

Ce rapport résume le contenu et les implications de la réglementation promulguée en avril 1998 par l'Environmental Protection Agency des États-Unis sur les normes d'émission visant les locomotives et les moteurs de locomotive en opération aux États-Unis. Les conséquences de ces normes pour le secteur ferroviaire canadien sont examinées, car il n'existe aucune norme d'émission en vigueur à l'heure actuelle pour les locomotives des chemins de fer canadiens; le secteur ferroviaire canadien a opté pour la surveillance volontaire. Étant donné que le matériel et le contexte d'exploitation des chemins de fer canadiens sont fortement intégrés à leurs contreparties américaines et que les économies canadienne et américaine sont de plus en plus imbriquées, les éléments touchés du secteur ferroviaire canadien comprennent les grands réseaux de chemins de fer et les chemins de fer régionaux, les constructeurs de matériel, les entreprises de révision, les fournisseurs de pièces, les établissements d'essai, les fournisseurs de carburant et de lubrifiants, les organismes de réglementation de l'environnement, les organismes d'innovation et de recherche, les groupes de défense d'intérêts publics, les associations industrielles et les associations d'employés. Ce rapport discute les possibilités d'action et de stratégie, avec bases de données connexes, en rapport avec les émissions des locomotives canadiennes.

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Railway Companies

British Columbia Railways - North Vancouver - Singh Biln - Chief Mechanical Officer
Canadian National Railways - Montreal - Bill Blevins - Operations & Maintenance Div.
Canadian Pacific Railway - Calgary - Ash Oleson - Manager, Emergency Response
GO Transit - Toronto - Peter Lloyd - Manager of Rail Equipment
Southern Railway of British Columbia - New Westminster - Don Irwin - Manager, Equipment Maintenance
West Coast Express - Vancouver - Eric Kosty - Operations Manager
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GE Transportation Systems - Erie, Pennsylvania - Nels Sandberg - Technical Support
General Motors of Canada - London - Rob Wright - Area Manager, Passenger Locomotive Sales
General Motors Electro-Motive Div. - La Grange, Illinois - David Brann - Tech Support

Other Engine Manufacturers

Caterpillar Inc. - Peoria, Illinois - Bill Passie - Technical Support
Cummins Est du Canada Inc. - Pointe Claire - Lloyd Crocker - Manager, Rail Accounts

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Energy Conversions Inc. - Tacoma, Washington - Paul Jensen - Director
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Engine Systems Development Company (ESDC) - Lachine - Malcolm Payne, President
Environmental Technology Centre (Environment Canada) - Ottawa - Fred Hendren, Chief, Mobile Sources Emissions Div.
Southwest Research Institute (SWRI) - San Antonio, Texas - Steve Fritz - Test Engineer

Associations

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Railway Association of Canada - Montreal - Bob Ballantyne - President
Transport 2000 - Ottawa - Harry Gow - President

EXECUTIVE SUMMARY

In April 1998, the U.S. Environmental Protection Agency (EPA) promulgated a rulemaking concerning emissions standards for locomotives and locomotive engines operating in the U.S.A. The EPA has designated stringent compliance requirements (to take effect 1 January 2000). These more stringent standards are a significant technical challenge and economic burden for the original equipment manufacturers (OEMs) and the U.S. railway operating sector.

The rulemaking is a major event in the history of North American railways. Because the equipment and operating context of Canadian railways is highly integrated with that of their American counterparts, the new standards also affect the Canadian railway sector, albeit not in a jurisdictional sense.

No legislated standards exist in Canada for locomotive emissions; rather, the Canadian railway sector has opted for voluntary monitoring. In December 1995, the Railway Association of Canada (RAC) entered into a voluntary monitoring action with Environment Canada to strive to cap locomotive emissions at 1989 levels for 1990 to 2005. In the absence of any Canadian standards, the rulemaking has become the technical regulation of reference for all locomotives and components to be manufactured, re-manufactured, repaired, or designed in Canada. The outstanding question is whether its contents will be used or adapted to cover locomotive operations in Canada.

The following constituents of the Canadian railway sector are concerned about the effects of the rulemaking: the mainline and regional railways, OEMs, re-manufacturers and overhaul facilities, after-service parts suppliers, testing establishments, fuel and lubricant suppliers, environmental agencies and regulators, innovation and research organizations, public advocacy groups, and industry and employee associations. This report addresses the implications for each of them.

The EPA standards focus primarily on reducing oxides of nitrogen (NOx) as well as particulate matter (PM) and hydrocarbons (HC), which are considered harmful to the health of humans, animals, and to the environment. Three tiers, or sets of standards, are applicable, depending on the date of a locomotive's original manufacture or re-manufacture. They cover both high-power line-haul and low-power switcher duty cycles:

- **Tier 0** (1973-2001 locomotives): 34% NO_x reduction, caps on other pollutants
- **Tier 1** (2002-2004 locomotives: 49% NO_x reduction, caps on other pollutants
- **Tier 2** (2005+ locomotives): 62% NO_x reduction, 50% PM and HC reductions

(Note: percentages are relative to a 1997 baseline)

The EPA estimates that locomotives operating in the U.S.A. emit over one million tons of NO_x per year, about five percent of the total NO_x emitted by all sources. Comparable data collected by the RAC show that 121,167 tonnes of NO_x were emitted by Canadian locomotives in 1997, some four percent of the transport total. The EPA

standards are expected to result in a 40 percent reduction in U.S. locomotive fleet NO_x emissions by 2010. Much of the expected reduction in NOx emissions will come in the first ten years of the program through the application of Tier 0 standards to existing locomotives when they are re-manufactured approximately every five years. It will be two or three decades before enough locomotives are manufactured to Tier 1 and Tier 2 standards to effect further reductions.

The EPA standards in themselves do not apply to carbon dioxide (CO_2) emissions, which Canada gives priority to as part of their Kyoto Protocol commitments. In fact, certain technology strategies to meet Tier 0 will probably result in poorer fuel efficiency (hence more CO_2 per unit of traffic volume). However, in the long term, the technological developments required to meet Tier 2 are expected to yield fuel-efficiency breakthroughs that will result in lower CO_2 emissions.

The emissions standards apply to newly manufactured locomotives and when locomotives are re-manufactured (every ten years or after 750,000 miles of operation). Exceptions are:

- Locomotives manufactured before 1973;
- Passenger locomotives manufactured before 2002 (Tier 0 deferred to 2007);
- Historic steam locomotives;
- Locomotives powered by engines less than 750 KW (1006 hp);
- Re-powered locomotives and switchers using certified non-road engines;
- Tier 0 locomotives owned and operated by small businesses (<1,500 staff);
- Exported locomotives;
- Manufacturer-owned or re-manufacturer-owned locomotives;
- Locomotives used for display, testing, or other development work;
- National security actions; and
- **Canadian* and Mexican locomotives used in border traffic and incidental forays in the U.S.A.**

*For the latter exemption, the case for the Canadian railways was the result of an intervention to the EPA by the Railway Association of Canada on 16 June 1997.

The EPA rulemaking has already caused the above-mentioned response from the Canadian railway sector and is having an economic impact. This impact involves the assignment of staff time, travel, and communication costs related to understanding and discussing the contents of the rulemaking. Canadian railways concerned about maintaining the value of older locomotive assets are considering upgrading them to Tier 0.

North American market opportunities exist for Canadian railways and equipment suppliers to provide products and services complying with the new EPA standards (and any eventual Canadian equivalent). This report includes a recommendation to implement a railway/government cooperative *Emissions Reduction Development Program* to assist the Canadian sector in developing this capability.

SOMMAIRE

En avril 1998, l'Environmental Protection Agency (EPA) des États-Unis a promulgué une réglementation concernant les normes d'émission pour les locomotives et les moteurs de locomotive en opération aux États-Unis. L'EPA a élaboré des exigences de conformité strictes (qui entreront en vigueur le 1er janvier 2000). Ces normes plus strictes représentent un défi technique et un fardeau économique pour les constructeurs de matériel et le secteur de l'exploitation ferroviaire aux États-Unis.

Cette réglementation est un événement majeur dans l'histoire des chemins de fer nord-américains. Étant donné que le matériel et le contexte d'exploitation des chemins de fer canadiens sont fortement intégrés à leurs contreparties américaines, ces nouvelles normes touchent également le secteur ferroviaire canadien, non sous l'angle juridique toutefois.

Il n'y a pas de normes juridiques au Canada pour les émissions de locomotive; le secteur ferroviaire canadien a opté pour un contrôle volontaire. En décembre 1995, l'Association des chemins de fer du Canada (ACFC) a entrepris un contrôle volontaire conjointement avec Environnement Canada pour tenter de limiter les émissions de locomotive au niveau de 1989 pour les années 1990 à 2005. En l'absence de normes canadiennes, cette réglementation est devenue la réglementation technique de référence pour toutes les locomotives et composantes qui seront construites, remises à neuf, réparées ou conçues au Canada. Il reste une question en suspens, celle de savoir si son contenu sera utilisé ou adapté pour couvrir les opérations des locomotives au Canada.

Les éléments suivants du secteur ferroviaire canadien sont touchés par les effets de la réglementation : les principaux réseaux de chemins de fer et les chemins de fer régionaux, les constructeurs de matériel, les entreprises de révision, les fournisseurs de pièces, les établissements d'essai, les fournisseurs de carburant et de lubrifiants, les organismes de protection et de réglementation de l'environnement, les organisations d'innovation et de recherche, les groupes de défense d'intérêts publics, les associations industrielles et les associations d'employés. Ce rapport examine les conséquences de la réglementation pour chacun de ces éléments.

Les normes de l'EPA visent surtout à réduire les oxydes d'azote (NO_x) de même que les particules en suspension et les hydrocarbures (HC), lesquels sont considérés nuisibles pour la santé des humains et des animaux et pour l'environnement. Trois paliers, ou ensembles de normes, sont applicables, selon l'année de construction ou de réusinage de la locomotive. Ils couvrent les cycles d'utilisation des locomotives de transport de ligne de grande puissance et ceux des locomotives de manoeuvre de faible puissance :

- **Palier 0** (1973-2001) : réduction des NO_x de 34 p. cent, aucune augmentation des autres polluants

- **Palier 1** (2002-2004) : réduction des NO_x de 49 p. cent, aucune augmentation des autres polluants
- **Palier 2** (2005 et après) : réduction des NO_x de 62 p. cent, réduction des particules en suspension et des HC de 50 p. cent

(Note : Les pourcentages sont établis à partir d'un niveau de référence datant de 1997.)

L'EPA estime que les locomotives en opération aux États-Unis produisent plus d'un million de tonnes de NO_x annuellement, ce qui correspond à cinq p. cent environ de la quantité totale de NO_x produits par toutes les sources possibles. Des données similaires collectées par l'ACFC indiquent que 121 167 tonnes de NO_x ont été produites par les locomotives canadiennes en 1997, ce qui correspond à quatre p. cent environ de la quantité totale produite par les moyens de transport. Les normes de l'EPA devraient réduire de 40 p. cent les émissions de NO_x par le parc de locomotives américain d'ici 2010. Une grande partie de la réduction prévue des émissions de NO_x se constatera dans les dix premières années du programme par suite de l'application des normes du palier 0 aux locomotives présentement en circulation quand celles-ci seront remises à neuf au bout de cinq ans de service environ. Il faudra ensuite de deux à trois décennies avant qu'il y ait suffisamment de nouvelles locomotives construites conformément aux normes des paliers 1 et 2 pour que l'on constate de nouvelles réductions.

Les normes de l'EPA ne s'appliquent pas aux émissions de dioxyde de carbone (CO_2) qui sont prioritaires pour le Canada vu les engagements pris par lui dans le cadre du Protocole de Kyoto. En fait, certaines stratégies technologiques visant à satisfaire les exigences du palier 0 vont probablement augmenter la consommation de carburant (d'où une plus grande quantité de CO_2 produite par unité de volume de trafic). Toutefois, à long terme, les développements technologiques nécessaires pour satisfaire aux stipulations du palier 2 devraient amener des progrès en matière de consommation de carburant qui réduiront les émissions de CO_2.

Les normes d'émission s'appliquent aux locomotives nouvellement construites et lorsque les locomotives sont remises à neuf (ces remises à neuf ont lieu tous les dix ans ou 750 000 milles de route). Les exceptions sont les suivantes :

- les locomotives construites avant 1973;
- les locomotives pour trains de voyageurs construites avant 2002 (le palier 0 est prolongé jusqu'à 2007);
- les locomotives à vapeur historiques;
- les locomotives dont la puissance est inférieure à 750 kW (1006 hp);
- les locomotives de ligne et de manoeuvre remotorisées avec des moteurs certifiés pour usage non routier;
- les locomotives de palier 0 appartenant à de petites entreprises (effectif inférieur à 1 500 employés) et exploitées par celles-ci;
- les locomotives exportées;
- les locomotives appartenant aux constructeurs et aux sociétés de remise à neuf;

- les locomotives de démonstration et d'essai, ou utilisées pour d'autres travaux de développement;
- les locomotives utilisées dans les opérations de sécurité nationale;
- **les locomotives canadiennes* et mexicaines utilisées dans le trafic frontalier et lors d'incursions occasionnelles aux États-Unis.**

*Cette exemption pour les locomotives canadiennes est le résultat d'une intervention auprès de l'EPA par l'Association des chemins de fer du Canada le 16 juin 1997.

La réglementation de l'EPA a déjà suscité la réaction ci-dessus du secteur ferroviaire canadien et a un impact économique. Celui-ci est constaté dans les dépenses consacrées au personnel, aux déplacements et aux communications pour comprendre et discuter le contenu de la réglementation. Les sociétés de chemins de fer canadiennes soucieuses de maintenir la valeur de leurs parcs de locomotives anciennes songent à mettre celles-ci à niveau au palier 0.

Les chemins de fer et les fournisseurs de matériel canadiens ont des débouchés sur le marché nord-américain pour des produits et des services conformes aux nouvelles normes de l'EPA (et aux normes canadiennes équivalentes éventuelles). Ce rapport contient une recommandation pour l'élaboration d'un *Programme de réduction des émissions de locomotives* basé sur la coopération entre les chemins de fer et le gouvernement pour aider le secteur canadien à atteindre cet objectif.

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GLOSSARY

Terminology of Diesel Locomotive Emissions and Related Technology

The medium speed diesel engine provides the predominant motive power for locomotives in operation on Canadian and American 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 the fuel and air until auto-ignition occurs (compression ignition, in comparison to using a spark plug). 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 (NOx). NOx is an invisible, toxic gas that can form fine aerosol particles of salts which contribute to acidic precipitation (commonly known as acid rain, snow or fog). If the combustion temperature is decreased to reduce NOx, this tends to increase the amount of uncombusted fuel that may be emitted as particulate matter (PM) or gaseous hydrocarbons (HC). HC reacts with NOx and other pollutants to form ground-level ozone (smog). Ozone and PM are associated with many adverse health and welfare effects, including respiratory illness, environmental damage and visibility problems.

Like all processes where combustion takes place, the combustion products emitted by diesel engines are a negative reality that has to be taken into account. This reality is currently being addressed by environmental and health regulators. The principal emissions under scrutiny are listed below.

NOx (Oxides of Nitrogen): these are the products of nitrogen and oxygen that result from high combustion temperature. NOx have implications for the health of humans, animals and the ecology. NOx reacts with hydrocarbons to form ozone in the presence of sunlight. The NOx emission level can be lowered be reducing combustion temperatures; one way is to retard injection timing and another is exhaust gas recirculation (but both result in higher fuel consumption and lower total power from the engine).

HC (Hydrocarbons): these are the result of incomplete combustion and the lubrication oil that is not oxidized during the combustion process. It is caused by partial combustion caused by short combustion time and low combustion temperatures (which are sometimes caused by excessive idling and operating engines at low power levels)

PM (Particulate Matter): this is residue of combustion consisting of unburned fuel and lubrication oil. It is known as primary PM. Increasing the combustion temperatures and duration can lower PM. It should be noted here that there is no NOx - PM tradeoff under the laws of physics. Technologies that control NOx (such as retarding injection timing) result in higher PM emissions. Conversely, technologies that control PM often result in increased NOx emissions. However, reducing NOx emissions will yield

reductions in ambient concentrations of secondary PM. For example, it is estimated that about 4 tonnes of nitrate particulate are formed from every 100 tonnes of NOx emitted.

CO (Carbon Monoxide): this gas is a by-product of the combustion of fossil fuels. Relative to other prime movers, it is low in diesel engines. CO is considered a 'greenhouse gas' and its accumulation in the atmosphere contributes to global warming.

SOx (Oxides of Sulfur): these are the result of burning fuels having a sulfur content. These emissions can be reduced by using fuel having a lower sulfur content.

O_3 (Ozone): a gas formed from the combination of NO_x, hydrocarbons and sunlight.

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, due to 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. The only way to reduce CO_2 emissions is to reduce the consumption of fossil fuels. For transportation applications, this means using more fuel-efficient engines, more fuel-efficient modes for the transport of passengers, goods and bulk commodities, or reducing mobility.

Technical Aspects of the Emissions Issue and Operational Development Trends

Despite continuous design improvements, diesel engines in general still contribute a significant portion of the NOx, PM and, to a lesser extent, the HC emissions from mobile sources. Spurred by the promulgation of more stringent emission standards, the Original Equipment Manufacturers (OEMs) are focusing on designing more effective controls for NOx, PM and HC. One strategy is to better manage the process of air and fuel delivery to the cylinder, reducing emissions production. Another strategy is to use after-treatment (or post combustion) technologies to break down or capture emissions. Diesel engines of the future, particularly those in railway applications, will likely use a combination of strategies to reduce harmful emissions. This could also include the use of alternative fuels. The principal emission control options include:

- **Fuel Delivery**: Designing electronic controls and improving fuel injectors to deliver fuel at the best combination of injection pressure, injection timing, injection rate shaping and spray location. This allows the engine to efficiently burn the fuel without causing the temperature spikes that increase NOx emissions. The temperature spikes can also be lowered by water injection into either the cylinders or the air manifold.

- **Air Intake:** Redesigning turbochargers, aftercoolers and intake valving to provide optimum air manifold pressure, temperature and routing of the intake air. This is important for managing the physical and chemical processes needed to achieve good air-fuel combustion. Exhaust gas circulation (mixing some exhaust gas with the intake air) is an established technique to manage emissions, but invariably lowers fuel efficiency. Another technique is to control intake air composition through, for example, the use of polymer membranes which effect a chemical reaction resulting in the separation of oxygen from the nitrogen. The oxygen is directed into the combustion chamber resulting in improved combustion characteristics. Similarly, techniques for adding hydrogen to the intake air can improve combustion.

- **Piston Design:** Special attention to the design of the piston face and compression ratio can result in combustion characteristics tailored to reduce emissions. Also, reducing oil consumption by improved oil scraper ring design and related details can reduce PM emissions.

- **After-treatment Technologies:** Using catalysts or particulate traps to convert or capture emissions between the cylinder exhaust valve and exhaust stack. Traps are used to remove and eventually burn particulate emissions. Catalysts for diesel engines are more complex than for automobiles and would be quite bulky for most locomotive installations. However, they hold promise for reducing NOx and PM by conversion to less harmful compounds.

- **Diesel Fuel Parameters:** Employing fuel additives and improving fuel properties such as raising the cetane number, lowering the aromatics content and decreasing sulfur levels can contribute to reduced NOx and PM emissions. Low carbon-intensive alternative fuels, particularly natural gas and dimethyl ether (made from natural gas or coal feedstock) offer NOx and PM benefits but lower energy efficiency.

Not to be overlooked in the quest to reduce emissions are the operational aspects of railway transportation. Any operational tactic that reduces the fuel consumed or diverts utilization from energy-intensive modes to the railways has merit. The Canadian railways have been able to reduce their specific fuel consumption ten percent between 1987 and 1997 (from 7.89 to 7.10 litres per net tonne-kilometre) by using such tactics as:

- **Higher-power, Higher-adhesion Locomotives:** This strategy permits fewer locomotives to pull the same train length, resulting in more optimum matching of power and, hence, economies in fuel consumption. Adhesion improvements include opting for microprocessor-controlled A.C. (versus D.C.) traction motors, air blast cleaning of the rail head and attention to wheel tread profiles.

- **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 shut down and restart (to avoid water coolant freezing) will lead to reduced overall locomotive emissions.

- **Improved Track Structures**: This strategy aims at reducing the friction of a train consist caused by such track features as sharp curves, grades, uneven roadbeds, track flexing and jointed rail. Also, double tracking sections of heavily-trafficked single-line trackage. As well, improved track structures facilitate train handling dynamics which impede smooth train operation.

- **Flange Lubrication:** This strategy supplements track structure improvements by lubricating the wheel flange contact area when traversing curves. Locomotives utilize on-board flange lubricators while track-side lubricators are used for rolling stock in the consist.

- **Reduced Railcar Rolling Friction:** Use of steerable-axle trucks and roller bearings have significantly reduced the rolling friction of trainsets.

- **Increased Railcar Gross Weight:** Allowable gross weight has recently been increased from 119,545 to 130,000 kilograms (263,000 to 286,000 pounds).

- **Reduced Railcar Tare Weight:** By the use of lighter weight aluminum car structures and designs to improve volume capacity, improved tare-to-gross weight ratios have been achieved.

- **Double-stack Container Cars:** This tactic permits shorter trains for the same container cargo volume.

- **Electro-pneumatic Brakes:** Use of this braking technology reduces draw on engine power to compress air for braking and, hence, reduces emissions.

- **Bi-modal Truck/Train Operations:** This strategy permits highway trucks to move by train between major terminals (thus effecting fuel and employee cost savings) and then continue to their final destination by road. Such examples of this are: a) the 'Iron Highway' service offered by Canadian Pacific Railway between Montreal and Toronto in which truck trailers are driven directly onto low-slung flat cars, and b) the Canadian National Railway's 'EcoRail' in which reinforced truck trailers are fitted with rail bogies.

IMPACT OF EPA LOCOMOTIVE EMISSIONS STANDARDS ON CANADIAN RAILWAY SECTOR

1. INTRODUCTION

All industrial sectors have come to realize that steps must be taken in their operations to reduce the negative impacts on the environment. Concern about their image in the eyes of the public vis-à-vis the environment plus the requirement and cost effectiveness issues to comply with environmental standards are now principal considerations on every organization's agenda. The Canadian railway sector is no exception (1).

In December 1995, the Railway Association of Canada (RAC) entered into a volunteer monitoring action with Environment Canada to strive to cap locomotive emissions at 1989 levels for the 1990 to 2005 time period (2). The subsequent promulgation in April 1998 by the U.S. Environmental Protection Agency (EPA) of its *Rulemaking on Emission Standards for Locomotives and Locomotive Engines* operating in the U.S.A. brought further attention to this subject in Canada (3). The EPA has focused on oxides of nitrogen (NOx), particulate matter (PM), hydrocarbons (HC), carbon monoxide (CO) and smoke (opacity). The EPA has designated stringent compliance requirements (to take effect 1 January 2000) governing limits on these emissions. Three tiers, or sets of standards, are applicable depending on the date of a locomotive's original manufacture or re-manufacture. They cover both high-power line-haul and low-power switcher duty cycles:

- **Tier 0** (1973 - 2001 locomotives), 34% NOx reduction, caps on other pollutants
- **Tier 1** (2002 - 2004 locomotives), 49% NOx reduction, caps on other pollutants
- **Tier 2** (2005 + locomotives), 62% NOx reduction, 50% PM and HC reductions

(Note: percentages are relative to a 1997 baseline)

In contrast, no legislated standards exist in Canada for locomotive emissions; rather, the Canadian railway sector has opted for voluntary compliance.

However, the North American railway sector is highly integrated, both from an operational as well as an equipment supply basis. Effectively, all American, Canadian and Mexican railways abide by the interchange rules of the Association of American Railroads (AAR). Hence, inherently, regulations and compliance requirements promulgated by U.S. authorities directly and indirectly affect the Canadian railway sector. This report identifies and analyzes (in an anecdotal manner) the envisaged impacts of the EPA rulemaking on the various constituents of the Canadian railway sector, inter alia:

- Class I Railway owners and operators
- Provincially-based, short line, industrial and passenger railways
- Original equipment manufacturers (OEMs)
- Locomotive re-manufacturers and overhaul facilities
- After-market parts sector
- Fuel and lubricant suppliers
- Testing establishments
- Federal and provincial environmental agencies and regulators
- Industry associations
- Public advocacy groups
- Railway employee organizations
- Research and innovation support organizations

The above-listed groupings of the Canadian railway sector employ approximately 50,000 employees overall, or which 46,000 work in the operating railways. Canada has two Class I railways, 42 short and regional railways and six passenger and commuter railways (1). As elaborated in Appendix A, of the 3,328 locomotives in freight operations (as of end of 1997), an estimated 2,000 will be retained in service over the next 10 to 15 years. Approximately 300 new locomotives are in the process of being delivered. Although not certified as such, their emissions meet at least the EPA Tier 0 level. The life expectations for the existing fleet are as follows:

4-Axle Switchers - 191 in service, of which 75% will be used for more than 10 years. Most built before 1987 having 2-stroke engines;

4-Axle Line-haul - 1,150 in service, of which 53% will be retained for 10 years.
Mostly built between 1954 and 1987. Medium horsepower;

6-Axle Line-haul - 1,878 in service, of which 63% will be retained for 10 years.
Mostly built between 1965 and 1986. Nominally 3000 hp.

A decision whether to re-fit these locomotives (when re-manufactured) to meet the equivalent of the EPA Tier 0 standards is envisaged to have not an insignificant impact in Canada. A lowering of the NOx, PM and HC emissions in line with those in the U.S.A. (shown in Figure 1) should result. Business opportunities for Canadian re-manufacturers and supporting services would increase. The asset value of the older locomotives would keep abreast of U.S. levels. However, the cost of the re-manufactured locomotives would increase, hence, imposing a burden on the operating railways (unless a form of tax rebate and other environment-based incentives were to be introduced, accordingly).

2. BACKGROUND

The release into the environment of the products of combustion in medium-speed diesel engines (as used almost exclusively for motive power on Canadian railways) is judged to have significance for:

- the health of humans, animals and terrestrial and aquatic ecosystems via the exposure to carcinogenic substances (namely NOx - which is a precursor to the formation of ground level ozone, which causes health problems such as damage to lung tissue, reduction of lung function and sensitization of lungs to other irritants) and,

- the climate changes brought on by global warming due to the increasing accumulation of carbon dioxide (CO_2) bringing about 'the greenhouse effect' which affects the balance between the portion of the heat from the sun that is reflected versus that retained in the atmosphere. Projected results are melting of ice caps and significant shifts in weather cycles.

Of these two factors, the U.S.A. appears more pro-active at addressing legislation to cap the type of emissions affecting the health of humans (the former identified above). Canada, on the other hand, is placing priority on voluntary actions to reduce greenhouse gas emissions affecting the latter, that is, sources of emissions causing global warming and changes in climate. It should be noted that California, motivated by the special atmospheric situation in its South Coast Air Basin, is foremost in producing legislation pertaining to emissions from internal combustion engines (4). It implemented legislation entitled the '*1994 California State Implementation Plan Measure M14'* which is supplemental to that of the EPA.

From a global perspective, guidelines for reducing emissions relating to climate change (the latter factor identified above) stem from the Kyoto Protocol on Climate Change (which Canada signed in December 1997). The Protocol sets out the goals to reduce greenhouse gas emissions. The commitment by Canada vis-à-vis the Kyoto Protocol is to reduce emissions of these gases (carbon dioxide, methane and nitrous oxides) by six percent of 1990 levels by year 2012 (5). The estimated actual reduction that will be required (all sectors) is 20 to 25 percent, based on projections of growth in emissions at current rates to the year 2012. The Canadian railway sector is an obvious contributor to achieving these goals, both by reducing its energy use and by being the recipient of modal displacement from less fuel-efficient transportation modes.

In April 1998, the Canadian federal and provincial ministers of energy and the environment met and agreed to develop a national implementation strategy on climate change, to establish a credit system to encourage early action to reduce greenhouse gas emissions and to promote voluntary action. Stemming from this, the National Climate Change Secretariat was established to oversee sixteen groups (called tables) to address

various sectors and special issues. One of these is the Transportation Table, with sub-committees addressing passenger and freight, each of which has, in turn, sub-committees covering the air, rail, road and marine modes. A concern by all participants of the various tables is that compliance with Kyoto Protocol emission reduction targets may therefore adversely affect Canada's economic competitiveness, create unemployment and reduce living standards. The railway sector is represented on all three levels of the Transportation Table by officers of the Railway Association of Canada.

As mentioned above, the U.S.A. has opted to give priority to the health of its citizens by legislating limits on the specific emissions that directly affect human health. These are NOx emissions, primarily, with PM and HC emissions as a secondary focus. To some degree, this priority goes against the goals of the Kyoto Summit in that, at least until 2005, fuel consumption will actually be increased in order to meet the EPA Tier 0 and Tier 1 limits. Hence, carbon dioxide emissions (a by-product of the total fuel combusted) will correspondingly increase and further aggravate conditions leading to climate change. Fuel consumption is degraded by two techniques for Tier 0 and Tier 1 emissions reduction, that is: retarding fuel injection timing and exhaust gas recycling.

At present, the locomotives operating in the U.S.A. emit over one million tons of NOx per year, about five percent of the total NOx emitted by all sources (6). Data for the Canadian emissions for 1997 are shown in Table 1 (7):

Table 1: Total Canadian Locomotive Emissions in Kilotonnes for 1997

NOx	CO	HC	PM	SOx	CO_2
121.67	23.22	6.14	2.89	5.61	5,989.79

(Source: *Locomotive Emissions Monitoring Program - Reporting Years 1996 and 1997* - compiled and published jointly by Environment Canada and Railway Association of Canada)

In terms of emissions per freight traffic unit (kg/1000 net ton miles), 1997 data are:

NO_x	CO	HC	PM	SOx	CO_2
0.568	0.108	0.029	0.014	0.026	27.956

The EPA standards are expected to result in a 40 percent reduction in U.S. locomotive fleet NOx emissions by the year 2010 as shown in Figure 1. Corresponding reductions in PM and HC are 16 and 15 percent respectively by 2010. The EPA has estimated that the overall cost-effectiveness of its the locomotive emissions standards is US $158 per ton of NOx, PM and HC reduced over the 40-year life of a locomotive (8).

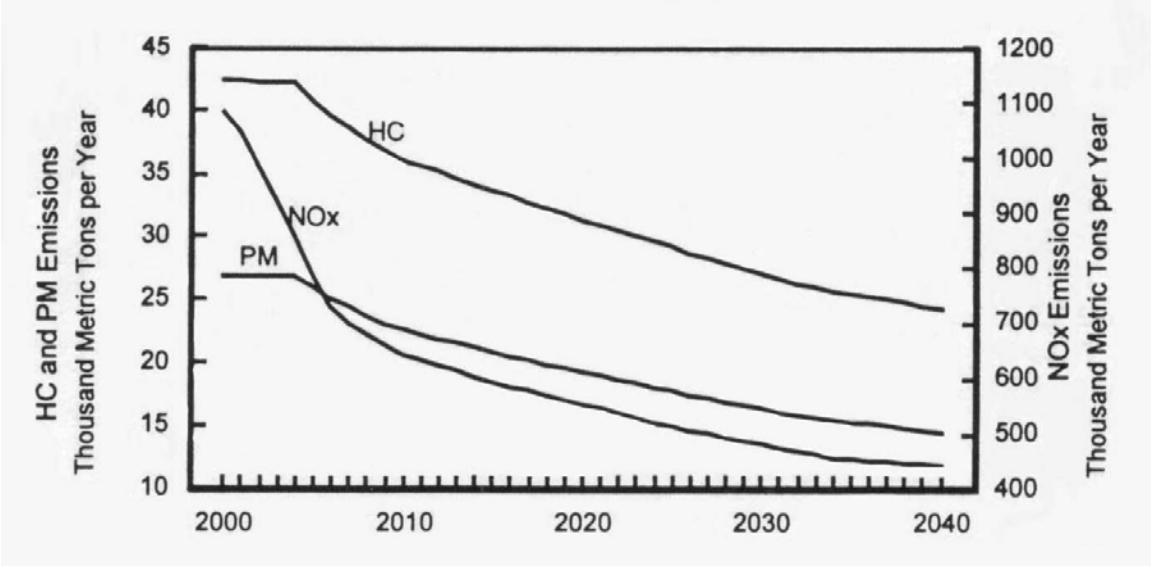

Figure 1: Projected Emissions for all Freight and Passenger Locomotives

(Source: U.S. Environmental Protection Agency)

In the U.S.A., much of the expected reduction in NOx emissions will come in the first ten years of the program due to the Tier 0 standards being applied to existing locomotives when they are re-manufactured approximately every five years. It will be two or three decades before locomotives manufactured to Tier 1 and Tier 2 standards are in sufficient numbers to effect further reductions.

Looking to the future, it will be of interest to monitor whether the legislated EPA standards will yield the targeted 40 percent reduction in U.S. locomotive fleet NOx emissions by the year 2010. Also of interest will be whether a similar percentage reduction in NOx emissions will occur by year 2010 in Canadian railway operations, but within a voluntary compliance regime.

3. APPLICABILITY AND COMPLIANCE LEVELS OF EPA LOCOMOTIVE EMISSIONS STANDARDS

The emissions standards apply to freshly manufactured (brand new) locomotives and re-manufactured locomotives. The standards remain applicable throughout the useful life of a locomotive. The definition of 'useful life' is based on the expected 'average period to next re-manufacture'. EPA has set this period as equivalent to either:

a) 750,000 miles of operation or ten years (whichever is reached first), or
b) when a MW-hr meter reading of 7.5 times the rated horsepower occurs (if locomotive is equipped with a MW-hr meter throughout its operations). Exceptions are:

- Locomotives manufactured before 1973;
- Passenger locomotives manufactured before 2002 (Tier 0 implementation deferred to 2007);
- Historic steam locomotives;
- Locomotives powered by engines less than 750 KW (1006 hp);
- Re-powered locomotives and switchers using certified non-road engines;
- Tier 0 locomotives owned and operated by small businesses (<1,500 staff);
- Exported locomotives;
- Manufacturer-owned or re-manufacturer-owned locomotives;
- Locomotives used for display, testing or other development work (including testing in revenue service);
- National security actions; and
- **Canadian and Mexican locomotives used in border traffic and incidental forays in the U.S.A.**

For the latter exemption, the case for the Canadian railways was the result of an intervention to the EPA by the Railway Association of Canada on 16 June 1997 (9).

The EPA emissions standards and current locomotive emission levels are listed in Table 2.

Table 2: Emissions Standards for Locomotives (g/bhp-hr)

Duty Cycle	HC*	CO	NOx	PM
Tier 0 (1973 - 2001)				
Line-haul	1.0	5.0	9.5	0.60
Switcher	2.1	8.0	14.0	0.72
Tier 1 (2002 - 2004)				
Line-haul	0.55	2.2	7.4	0.45
Switcher	1.2	2.5	11.0	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.20
Switcher	0.6	2.4	8.1	0.24
Current Estimated Locomotive Emission Rates (1997)				
Line-haul	0.5	1.5	13.5	0.34
Switcher	1.1	2.4	19.8	0.41
** - HC standard is in the form of THC (total hydrocarbon) for diesel engines. For locomotives and locomotive engines fueled by alcohol or natural gas, equivalent THC standards apply.*				

Allowance is made for alternative standards for CO and PM to be used by manufacturers or re-manufacturers when seeking certification (for which both emissions must be complied with) as shown in Table 3.

Table 3: Alternative CO and PM standards (gm/bhp-hr)

	CO	PM	CO	PM
	Line-haul Cycle		**Switcher Cycle**	
Tier 0	10.0	0.30	12.0	0.36
Tier 1	10.0	0.22	12.0	0.27
Tier 2	10.0	0.10	12.0	0.12

The smoke opacity standards are listed in Table 4.

Table 4: Smoke Standards for Locomotives (percent opacity, normalized)

	Steady-state	30-sec peak	3-sec peak
Tier 0	30	40	50
Tier 1	25	40	50
Tier 2	20	40	50

Figure 2 illustrates where several popular locomotives now in operation in the U.S.A. are positioned relative to the new EPA standards (10). All these locomotives are required to meet Tier 0 standards when they are re-manufactured after 1 January 2000. Some could possibly meet Tier 0 standards by retarding injection timing of the diesel engine (but at a fuel and power penalty). Others will be the targets for the development of retrofit kits for which certification must first be obtained from the EPA before provided commercially to railway locomotive operators (11). These EPA-certified retrofit kits are expected to be licensable to locomotive re-manufacturers, overhaul facilities and parts suppliers, some of which are likely to be sited in Canada. The details regarding the certification of retrofit kits are summarized in Section 4 and Appendix B. The relevant documentation can be accessed electronically at *http://www.epa.gov/oms/locomotv.htm* and the certification templates can be accessed at *http://www.epa.gov/oms/certdata.htm* requiring *Filemaker Pro* software for downloading.

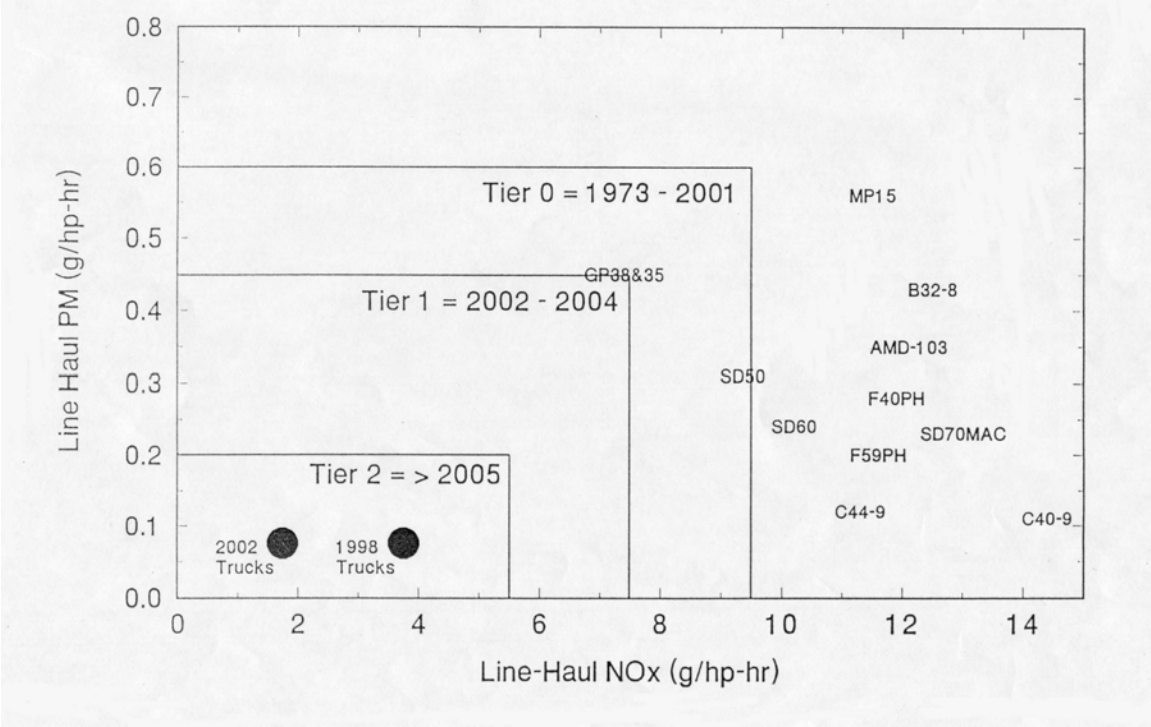

Figure 2: EPA Locomotive Exhaust Emissions Regulations

Source: Southwest Research Institute

4. SUMMARY OF THE EPA RULEMAKING

The U.S. Government's Clean Air Act (section 213) directs the EPA to adopt emissions standards applicable to new locomotives and to new engines used in locomotives. The resulting regulation was that promulgated in the U.S. Government's Federal Register dated April 16, 1998, pages 18978 to 19084, regarding the final EPA rulemaking entitled, *Emission Standards for Locomotives and Locomotive Engines* and detailed, specifically, in Part 92 (*Control of Air Pollution from Locomotive and Locomotive Engines*) of Title 40 of the *Code of Federal Regulations,* with amendments also to Parts 85 and 89 (3). Pages 18978 through 18997 contain summaries and information supplementary to the details contained in Part 92. The rulemaking is administered by the EPA Office of Mobile Sources with sites in Washington, D.C., and Ann Arbor, Michigan. The relevant documentation can be accessed at *http://www.epa.gov/oms/locomotv.htm* and the certification templates can be accessed at *http://www.epa.gov/oms/certdata.htm* requiring *Filemaker Pro* software for downloading.

It is in Part 92 of the U.S. *Code of Federal Regulations* (CFR) where the extensive and carefully worded provisions are detailed to implement the standards and to ensure that the standards are met in use. These provisions include:

- test procedures for a manufacturer or re-manufacturer to obtain EPA certification;
- production assembly-line compliance testing; and
- in-use compliance testing procedures.

Note that failure to comply can result in legal actions and fines. Also described in the CFR are emissions averaging, banking and trading procedures to provide flexibility in achieving compliance. To minimize economic hardship on small railways (defined by the U.S. Small Business Administration as having less than 1500 employees), the EPA has ruled that they are exempt from the Tier 0 re-manufacturing requirements for their existing fleets. The EPA has also ruled that in-use compliance testing only applies to the large Class 1 freight railways. However, small parts suppliers and re-manufacturing businesses are not exempt from compliance. A small parts supplier must either certify a re-manufacturing system that uses its parts or it must produce parts that others can use in certified re-manufacturing systems.

The regulations are the result of five years of consultations with the entities and jurisdictions involved plus the concerned public. Except for California's *Measure M14,* the EPA regulations preempt state and local requirements; a position arrived at by the successful intervention of the American Association of Railroads seeking to avoid having to meet differing standards within the various U.S. states traversed by the operating companies' rail lines.

Part 92 of the regulation contains twelve subparts and four appendices, with each subpart containing a number of sections, as follows:

- Subpart A - General Provisions for Emission Regulations for Locomotives and Locomotive Engines (Sections 92.1 through 92.12
- Subpart B - Test Procedures (Sections 92.101 through 92.133)
- Subpart C - Certification Provisions (Sections 92.201 through 92.216)
- Subpart D - Certification Averaging, Banking and Trading Provisions (Sections 92.301 through 92.310)
- Subpart E - Emission-related Defect Reporting Requirements, Voluntary Emission Recall Program (Sections 92.401 through 92.408)
- Subpart F - Manufacturer and Re-manufacturer Production Line Testing and Audit Programs (Sections 92.501 through 92.517)
- Subpart G - In-use Testing Program (Sections 92.601 through 92.607)
- Subpart H - Recall Regulations (Sections 92.701 through 92.709)
- Subpart I - Importation of Nonconforming Locomotives and Locomotive Engines (Sections 92.801 through 92.805)
- Subpart J - Exclusion and Exemption Provisions (Sections 92.901 to 92.911)
- Subpart K- Requirements Applicable to Owners and Operators of Locomotives and Locomotive Engines (Sections 92.1001-92.1006)
- Subpart L - General Enforcement Provisions and Prohibited Acts (Sections 92.1101 through 92.1108)

Appendix I - Emission-Related Locomotive and Engine Parameters and Specifications
Appendix II - Interpretive Ruling for Section 92.705 - Remedial Plans
Appendix III - Smoke Standards for Non-normalized Measurements
Appendix IV - Guidelines for Determining Equivalency between Emission Measurement Systems

Elaboration of the priority elements of Subparts A to L is contained in Appendix B.

5. IMPACT OF EPA RULEMAKING ON THE CANADIAN RAILWAY SECTOR

On the surface, one could conclude that the EPA rulemaking on locomotive emissions standards operating in the U.S.A. has no direct impact on the Canadian railway sector. This is because the EPA rulemaking is only applicable to locomotives operating in the U.S.A. and the Railway Association of Canada has obtained an exemption from the EPA for Canadian-owned locomotives making cross-border and incidental forays in the U.S.A. In addition, no national or provincial standards govern railway locomotive emissions in Canada. However, there are several implications of an indirect nature for the Canadian operating railways and, certainly, there is an impact for other members of the Canadian railway sector such as locomotive and engine re-manufacturers, small parts suppliers and technical support organizations that serve the North American market. Also, public advocacy and employee interest groups are paying attention to such environment-related initiatives in the U.S.A. and as with such developments, many times what happens in the U.S.A. is a precursor for a Canadian action or response.

Already, the EPA rulemaking has caused an economic impact and response from the Canadian railway sector. The economic impact is in the form of the assignment of staff time, travel and communication costs to understand and discuss the contents of the Rulemaking. The magnitudes are difficult to quantify but are estimated to be several person-years and several hundreds of thousands of dollars per year. For instance, following consultations with its members, the RAC made an intervention (supported with extensive documentation) to the EPA seeking dispensation for Canadian locomotives making forays into the U.S.A. Environment Canada convened a workshop in Winnipeg in June 1999, wherein locomotive emissions and their implications were a focal point. Some 150 persons attended from across Canada, which is an indicator of the staff resources concerned about the subject in Canada.

Over the next few years, it is judged that the staff time and expense will rise steadily for constituents of the Canadian railway sector influenced by measures related to the EPA rulemaking. In the absence of any Canadian standards, the EPA Rulemaking has become the technical regulation of reference for locomotive design specifications in North America. Hence, for all locomotives and components manufactured, re-manufactured, repaired or designed in Canada, the EPA rulemaking will be the pervasive reference. The outstanding question is whether its contents will be used to cover locomotive operations in Canada.

Perhaps the most significant impact of the EPA rulemaking for the Canadian railway sector is that it raises the question as to whether a Canadian equivalent should be promulgated. It is the judgement of the author that the Canadian railway sector cannot indefinitely take a laissez-faire attitude regarding the emissions of its locomotives. Pressure is mounting for all emissions-producing sectors to take action to reduce stress on the atmosphere. The railway emissions problem affects a multiplicity of constituents

and jurisdictions. The resolution is paced by political will, legislated compliance standards, enabling technology and economic viability. It is hoped that these four factors can be harmonized and emissions-reducing tactics can be implemented in a coordinated fashion. The EPA rulemaking is definitely a precursor for a more intensive examination in Canada regarding emissions into the atmosphere by railway locomotives.

If Canada were to opt to promulgate emissions standards equivalent to the EPA Rulemaking, two scenarios are suggested for their provisions to be adapted into the Canadian legal system:

- the 'rubber stamping' and translation into French of the provisions contained in the U.S. Government's CFR 92 document; or
- the preparation of provisions specifically applicable to the Canadian operating and weather conditions and cultural context, plus done in a way to spur technological advancement in all parts of the Canadian railway sector.

Regarding the latter scenario of using Canadian-developed provisions to spur technological advancement to reduce emissions in Canada, it is recommended that a well-coordinated emissions reduction development program be devised and implemen-ted. It is recommended that implementation be led by the railway sector with government facilitation. A railway sector model, or precedent, for such an emissions reduction development program is the recently-completed American Association of Railroads (AAR) ten-year, $10 million Track-Train Dynamics Program. This highly-successful cooperative railway-government program was aimed at improving North American rail safety and productivity via the development, testing and implementation of a wide range of technological improvements. In this case, the railways' involvement was motivated by enhanced operating economics and improved safety. In the case of emissions reductions, the railways' involvement would be motivated by maintaining the value of their locomotive assets (regarding re-sale considerations) and by contributing to the Canadian 'public good'. An incentive for the latter is the long-range goal for the railways is to be the transport mode of choice so as to contribute to lowering emissions into the atmosphere, reducing highway congestion and increasing safety.

The first step in the consideration to embark on an emissions reduction development program for the Canadian railway sector would be the preparation of a plan outlining the measurable objectives, envisaged scope, expected participants and order-of-magnitude cost estimates. It must be observed, though, that even if 'Canadian-developed' provisions for such a program were opted for, they would inherently encompass most of the provisions of the EPA rulemaking because of the high interaction of the Canadian railway sector with its U.S. counterparts.

6. IMPLICATIONS FOR CONSTITUENTS OF RAILWAY SECTOR

6.1 Implications for Canada's Class I Railway Owners and Operators

The EPA rulemaking on emission standards applies only to locomotives operated by American railways in the U.S.A. Hence, the EPA standards do not apply to railway operations in Canada. However, because of the traditional strong interaction between the American and Canadian railway sectors, especially on technical standards due to common membership in the American Associations of Railroads (AAR), plus the intertwining of the Canadian and American economies and attitudes, what happens in the U.S.A. inherently cannot be ignored by the Canadian side. One thing that the Canadian railways, individually and within the forum of the Railway Association of Canada, must keep in mind is the possibility that the EPA standards could become a de facto standard or template for standards for locomotive emissions regulation in Canada.

Another aspect of why the Canadian mainline railways cannot ignore the EPA rulemaking is that, as owners of Class I freight railways in the U.S.A., they have corporate responsibility for their American subsidiaries to comply with the EPA standards. Canadian National Railways owns the Illinois Central (with 365 locomotives) and the Grand Trunk Western Railroad (with 244 locomotives). Canadian Pacific Railway owns the Soo Lines with 333 locomotives. These subsidiaries will be obligated to expend considerable in-house resources to accommodate the burden of compliance. This burden will have an obvious impact on overhead expenses and hence, the balance sheet of the corporation as a whole. In addition, these American subsidiaries will be obligated to budget incremental funding for re-manufactured locomotives meeting Tier O standards (estimated by the EPA to be an extra US $80,000 per locomotive).

Regarding the burden to an American subsidiary to accommodate and comply with environmental and similar regulations, the rulemaking in Item C of Section IX (page 18997 of the rulemaking) defines 'burden' as the total time, effort or financial resources expended by persons to generate, maintain, retain, disclose or provide information to or for a federal agency (3). This includes the time needed to:

- review instructions;
- develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating and verifying information, processing and maintaining information, plus disclosing and providing information;
- adjust the existing ways to comply with any previously applicable instructions and requirements;
- train personnel to respond to a collection of information;
- search data sources;
- complete and review the collection of information; and
- transmit or otherwise disclose the information.

The resulting impact of this burden will be an increase in cost of doing business without a concomitant increase in revenue. The result will either be an increased operating ratio (cost to earn a unit of revenue) or increased tariffs to customers (which may not be possible to effect depending on the competitive situation).

Canadian locomotives used in border traffic and incidental forays in the U.S.A. are exempted from the rulemaking. However, EPA officials have stated in meetings and workshops that 'incidental forays' are deemed to be 'less than five percent' on a time basis (12). This is equivalent to only one day in twenty for such occurrences and, hence, if exceeded, could raise the possibility of a warning from the EPA or an intervention from an American railway claiming unfairness. It could also have implications for the traditional practice of transferring locomotives between the Canadian parent railways and their American subsidiaries during times of extra-ordinary demands for motive power. It could lead to such strategies as transferring older locomotives from U.S. subsidiaries of Canadian railways northward for operation in Canada so as to avoid, or defer, the expense of upgrading them to Tier 0 standards.

The new EPA standards are spurring technology development by the original equipment manufacturers (OEMs), namely, General Motors Corporation's Electro-Motive Division, General Electric's GE Transportation Division and Motive Power (Boise) with Caterpillar engines. According to the Engine Manufacturers Association, these improvements will accrue benefits to Canadian railways when they purchase locomotives incorporating the resulting technological advancements (13). If the OEMs are successful in developing and delivering locomotives to meet Tier 1 and Tier 2 standards, the Canadian mainline railways will subsequently benefit from the diesel engine technology spurred by the EPA standards.

It is envisaged that the commercially competitive nature of the OEMs will spur a variety of other improvements and hence further benefit the operating railways. The benefits will not only result from improved economics by its American subsidiaries (within the enhanced EPA emissions regime), but also the Tier 1 and Tier 2 locomotives that will be offered to the Canadian railways will incorporate, inter alia, more efficient engine combustion technology and improved wheel/rail adhesion. At the same time, the Canadian railways can demonstrate that they are taking steps, in line with their American counterparts, to operate locomotives with lower exhaust emissions. This will produce kudos for the Canadian railways from environmental authorities, public interest groups, unions and railway employees (many of whom have expressed concerns about their own health vis-à-vis locomotive emissions). Although not yet firmly determined, it is estimated that the amortized cost of developing new locomotives to meet Tier 1 and Tier 2 standards will raise the delivery price to the Canadian railways about 15 percent (14).

The new EPA standards raise implications for Canadian railways as to whether to have their locomotives re-manufactured to Tier 0 standards when their overhaul next falls due, rather than to their original configuration (when purchased between 1973 and 1999).

There is no obligation for Canadian railways to take this step except from consideration to maintain the value of its assets. As North America is essentially one market for new and used railway equipment, it would seem to be in a Canadian railway's interest, when selling its used locomotives, that they should meet standards being enforced in both Canada and the U.S.A. As the U.S.A. has ten times the Canadian market, it would seem advantageous for a Canadian railway to invest in the Tier 0 update to maximize the value of its assets. This would apply to both the book value and expected selling price of a used locomotive. Careful cost-benefit analyses would have to be applied in order to decide whether to opt to re-manufacture to Tier 0 standards.

It goes without saying that the Canadian mainline railways are now required to commit considerable executive and technical staff time and resources to monitor and keep abreast with the introduction of the EPA rulemaking in the U.S.A., and similar environmental issues. They must handle the multiplicity of queries and attend the various meetings and workshops in this regard. As Canadian railways are now performing both new locomotive assembly (on behalf of the OEMs) and undertaking re-build contracts for railways throughout North America, a complete understanding of the technical, industrial engineering and production management requirements related to incorporation of the EPA's Tier 0, Tier 1 and Tier 2 emission standards is mandatory. It is estimated that this requirement could consume three to five person-years of staff time per railway; hence affecting the Canadian railways' corporate balance sheets. Having the in-house capability to handle technology to meet Tier 0, Tier 1 and Tier 2 could lead to future revenue-generating opportunities for Canadian railways.

6.2 Implications for Provincially-Based, Short Line, Industrial and Passenger Railway Owners and Operators

The impact of the rulemaking on provincially-based railways, short line railways and industrial railways (either federally or non-federally regulated) is considered to be minimal because their operations remain completely within Canada. This would apply similarly for private and public passenger train owners and operators. For passenger locomotives operating in the U.S.A., EPA has delayed the effective date of implementation of the Tier 0 requirements until January 1, 2007.

In the U.S.A., the short lines and industrial railways affected are only those having more than 1500 employees. These railways consume only ten percent of the fuel used by the fleet and, hence, having to meet the EPA standards is seen as an economic hardship with minimal benefit. It is usual for smaller railways to not actually re-manufacture their locomotives or engines (as defined by EPA), but instead to rebuild them periodically in a manner that does not result in a 'new' unit. For example, they are more likely to replace power assemblies only when they fail (rather than, say, on a regular 'useful life' basis).

The principal impact for the smaller Canadian railways would be of an accounting nature, that is, maintaining the value of their assets. By having their locomotives

re-manufactured to meet Tier 0, Tier 1 or Tier 2 levels in future would maintain the asset value of the locomotive for sale in the U.S.A. marketplace sometime in the future (15). Similarly, meeting EPA emission standards would permit these locomotives to be leased for use in American railway operations, should the circumstance present itself. Obviously, upgrading locomotives to meet the new EPA standards would only be opted for after careful cost-benefit analyses within a long-range business plan. There would be not only an initial capital cost for the re-manufacture but also more attention would be required to keep the engines properly maintained.

Another implication for such railways if they possessed locomotives meeting EPA standards would be the positive, albeit somewhat subjective, benefit as seen through the eyes of the local publics. Local or regional railways wish to be seen as good corporate citizens. Railways are inherently 'environmentally friendly' in the eyes of the public, but this image can be shattered by a smoky diesel locomotive. One tangible way for local railways to reinforce this and underpin public relations is to opt to up-grade their locomotives to meet the new EPA emission standards and advertise this to their local publics. Such steps would generate kudos from public advocacy groups, unions and employees and regional governments.

Local or regional railways make excellent demonstration sites for testing and evaluating environmentally friendly technologies because the equipment can be handled and monitored easily under controlled conditions. An example of such a demonstration could be the testing and evaluation of locomotives operating on alternative fuels, such as natural gas. The extra-ordinary costs associated with such an evaluation could be the basis of cooperative agreements with applicable governmental agencies. Such a candidate railway possessing technical support capability is BC Rail.

6.3 Implications for North American Original Equipment Manufacturers (OEMs)

A considerable engineering development effort will be required to meet the new EPA emissions standards. The OEMs will obviously bear the brunt of the development challenges to deliver new locomotives complying with Tier 1 standards (to take effect 2002) and Tier 2 standards (to take effect 2005 and afterwards). An observation of the author is that there is some uncertainty that the OEMs will be able to deliver locomotives meeting these standards in the required timeframe and for a price that the Class I railways are willing to pay. As the technical development is being driven by government regulation, it might result in interventions by the U.S. railway sector either to the EPA to delay the introduction dates or to seek financial assistance. The OEMs are facing serious technical and financial risks to develop Tier 1 and Tier 2 compliant locomotives. If the North American railway sector delays, defers or otherwise avoids purchasing these new emissions-compliant but more expensive locomotives, it could result in significant hardship for the OEMs.

Also, the OEMs are being counted on by the railways to provide 'EPA certified re-manufacturing kits' that, when installed at time of overhaul in an existing locomotive manufactured since 1973, will result in a locomotive meeting Tier 0 emission standards. These 'certified kits' will vary depending on the engine family and duty cycle concerned. The Tier 0 rebuild market is by far the largest, with estimates ranging from 12,000 to 20,000 units. The OEMs will have competition from the re-manufacturers, many of which are expected to develop their own kits and have them certified by EPA. Both the OEMs and the re-manufacturers can either install the kits themselves or opt to license their proprietary kits to installers such as overhaul job-shops and some railways. It is expected that the marketplace will decide the content and price of the kits. Whereas it would seem advantageous for the OEMs and re-manufacturers to pool their resources to develop kits to meet the standards, it appears that the competitive culture of the U.S. private business sector precludes any R&D and design collaboration (15). It is understood that the OEMs are undertaking kit development using a combination of in-house and contracted expertise. As of June 1999, however, no kit developer has yet applied to EPA for a certification template.

A Canadian element to the delivery of locomotives meeting Tier 1 and Tier 2 is that General Motors plans that the majority of all new EMD locomotives will be assembled at the General Motors of Canada manufacturing facility in London, Ontario, beginning January 2002. The EPA standards require production-line testing so as to be certain that certification designs have been translated into production locomotives that meet the applicable standards before excessive emissions are generated in-use. One percent of the annual production or a minimum of one test per year per engine family is required. This suggests that General Motors of Canada must arrange to have this testing done either by marshalling in-house capability or by utilizing contracted testing capability.

6.4 Implications for Canadian Re-Manufacturers and Overhaul Facilities

The decision that has to be taken by Canadian locomotive re-manufacturers is whether to focus on obtaining an EPA certification for a technology that will bring an engine model up to Tier 0 or higher. A Canadian re-manufacturer can either develop its own technology and go through the process of obtaining EPA certification or can license the technology from an OEM or another re-manufacturer (likely based in the U.S.A.). Another alternative is for the Canadian re-manufacturer to opt to replace the diesel engine with one having been certified by an OEM to meet either Tier 1 or Tier 2. The challenge here is not so much being able to meet the EPA standards as to find operators to commit their railways be the launch site for the re-manufactured locomotive with an engine new to the North American railway scene. The likely candidate engine suppliers for medium-speed engines are Caterpillar in the U.S.A. and Ruston, the Alstom subsidiary in England. Cummins is exploring whether to offer its higher-speed diesel engines for North American railway applications (now in use on European and Asian railways).

For re-manufacturers to develop proprietary technology and obtain EPA certification for a Tier 0 retrofit kit, a considerable investment would be required. An EPA study estimated that several hundreds of thousands of dollars per engine family would be required. In addition, the holder of the certified kit would assume considerable liability for auditing installers, conducting in-use testing of the engines and solving problems that are identified by in-use tests. The re-manufacturers would recover their investment by either actual installation, licensing of installers or sales of parts and services. The EPA estimated that the extra cost of re-manufacturing to Tier 0 standards is US $80,000 per locomotive.

6.5 Implications for the After-Market Parts Sector in Canada

It is presumed that the whole of the North American railway sector is the marketplace for the Canadian after-market parts suppliers. For these suppliers, vis-à-vis the new EPA standards, the challenge is to associate themselves with a manufacturer or re-manufacturer that has obtained EPA certification for a retrofit package. Canadian after-market suppliers must ensure that their parts are equivalent technically to those specified in the certified retrofit package. The EPA rulemaking makes provision that no brand name parts can be specified in a retrofit package. Anyone supplying parts meeting the technical specifications is eligible. The impact of the rulemaking for these constituents of the Canadian railway sector is the need to accommodate the technical modifications, update their technology and ensure price competitiveness.

6.6 Implications for the Canadian Fuel and Lubricant Suppliers

Fuel is the largest single cost item in railway operations. To date, in comparison with engine technology development, little research has focused on how fuel properties influence emissions (16). The specifications of the fuels and lubricants used can influence the amount and nature of the emissions from a diesel engine. Specifications of the fuel provided to the railways vary from region to region in North America depending on the characteristics of the source crude and the refinery capabilities.

More stringent fuel specifications will likely come into existence over a longer time period than will engine improvements developed by the OEMs to meet Tier 1 and Tier 2 EPA standards. It is uncertain what and who will be the stimulus to demand more stringent fuel and lubricant specifications for railway applications. The operating railways will be reluctant because of the likely concomitant increase in cost of the upgraded fuel.

Opting for alternative less carbon-intensive fuels could be an option to influence technological advancement by the oil refining sector. The use of natural gas (as a less polluting and plentiful fuel) in locomotive diesel engines is a perfected technology. The mounting of a demonstration of a natural gas fueled railway operation would appear to have merit, not only to show reduction in emissions but also to be a spur to the refining sector to compete on emissions reduction with its conventional diesel fuels.

Associated with fuels and lubricants is the plethora of additives that are available on the market. Some originate in Canada. There does not seem to be consensus among the railway operators as to the relative advantages of one type of additive versus another. For certification of an new engine or retrofit kit, the EPA (in Sub-part 92.113) does permit diesel fuel to contain nonmetallic additives as follows: cetane improver, metal deactivator, antioxidant, dehazer, antirust, pour depressant, dye, dispersant and biocide.

6.7 Implications for Testing Establishments

In order to obtain EPA certification for a particular locomotive and engine model the it meets either Tier 0, Tier 1 or Tier 2 standards, the OEMs and re-manufacturers are required to demonstrate that the particulars of the emissions produced have been measured and categorized according to the procedures identified in the Rulemaking. These are best done by established Testing Facilities. Candidates in Canada having the equipment and staff expertise are the private company, Engine Systems Development Company (ESDC) in Lachine and Environment Canada's Environmental Test Centre in Ottawa. Testing not only is required to obtain the initial EPA certification but also there are requirements for production-line testing (for such sites as the General Motors of Canada assembly plant in London, Ontario, railway shops such as CP Rail's in Calgary and others, such as Alstom Canada Transport in Montreal). It is foreseen that a Canada-based testing facility that has prepared itself should have a market throughout North America.

It has been noted in the various workshops on the subject that the testing requirements to obtain EPA certification or compliance require specialized equipment and expertise. Estimates are of the order of $5 million to establish a test facility from scratch. To undertake a locomotive certification test on a one-at-a-time basis is estimated to cost US$30,000 to $40,000.

It has also been noted that the technical basis for establishing the NOx correction factor for temperature and humidity has yet to be done. Similarly, how best to test to show high altitude compliance is another uncertainty. There may be other shortfalls in the testing procedure as, in fact, no application for certification of a railway medium speed engine or retrofit kit has been yet been submitted to the EPA.

6.8 Implications for Federal and Provincial Environmental Agencies and Regulators

The principal federal government departments having a purview (or potential purview) regarding railway locomotive emissions are Environment Canada and Transport Canada. At present, there are no legislated standards to be enforced. From an equipment technology aspect, it could be presumed that the contents of the EPA rulemaking are the default technical reference for any organization based in Canada dealing with locomotive and locomotive engine manufacture, re-manufacture, overhaul and design. However,

whether there will be steps to adapt some, or all, of the contents of the EPA rulemaking for enforcement on operating Canadian railways is an open question.

6.9 Implications for Industry Associations

The principal association concerned is the Railway Association of Canada (RAC). This is because, for Canada, the largest impact of the rulemaking is on the operating railways, in the long run. The position of the RAC is that the railways are in business to make money and any consideration to introduce standards affecting their business should be addressed via consultation and consensus (17). The RAC favours self-monitoring of any standards regarding emissions from locomotives operating on Canadian railways. The RAC recognizes that, in all likelihood, new locomotives purchased over the next decade from the U.S.-based OEMs will, inherently, meet Tier 1 or Tier 2 EPA standards. Motivation for Canadian railways to upgrade existing locomotives to Tier 0 would seem to be associated with individual decisions to maintain the value of their locomotive assets for possible resale in the U.S. marketplace.

6.10 Implications for Public Advocacy Groups

Such groups as Transport 2000 and concerned citizens groups in cities where railway operations are dominant (such as in Toronto, Hamilton and Vancouver) are advocating, on the one hand, the transfer of more transport from the road to the rail mode and, on the other hand, that all modes reduce their contribution of harmful emissions into the atmosphere. They appear to be inherently in favour of any policy initiative or development that is focused on reducing environmental degradation. They closely watch developments outside Canada and advocate their introduction into the Canadian context. The implications of the EPA rulemaking for such groups is to arm them with a quantifiable reference to weigh the pros and cons regarding adoption in Canada.

6.11 Implications for Railway Employee Organizations

Such employee organizations as the Brotherhood of Railway Locomotive Engineers and associated railway trade unions view the EPA rulemaking as an instrument to reinforce their long-standing claims regarding the health effects of exposure to diesel engine emissions. For example, the Brotherhood is targeting having air conditioning in the driver cabs of locomotives, something the operating railways have resisted for cost considerations. The implication of the EPA rulemaking in this case is that brings attention to the fact that the U.S. Government has taken steps to cause the significant reduction of emissions harmful to human health. The Canadian railway employee organizations expect to see some equivalent action taken in Canada.

6.12 Implications for Research and Innovation Support Organizations

The perfection of technology aimed at reducing harmful effects on the environment is rarely an activity that the transportation sector will fund on its own due to the fact that the result is generally a qualitative rather than quantitative return for the investment. This is all the more so if the requirement is driven by a governmental standard or ruling such as the EPA rulemaking. However, the EPA rulemaking has created a requirement, albeit in the U.S.A. initially, for technology to meet more stringent emission standards. Canada has potential suppliers that could develop and provide this technology into the North American marketplace (18) (19). To stimulate such activity in Canada, support to the industry by governmental innovation agencies would seem justifiable.

Industrial development themes aimed at perfecting technology meeting the equivalent of the EPA emission standards would appear to fall into three categories:

a) technology being developed by a Canadian re-manufacturer for which EPA certification would be sought;

b) the testing and evaluation under controlled conditions on an operating railway of emissions-reducing technology; and

c) the testing and evaluation under controlled conditions on an operating railway of low carbon-intense alternate fuels such as natural gas, synthetic fuels, etc.

Candidate innovation agencies that provide cost-shared support for item a) objectives are Industry Canada's Technology Partnerships Canada (TPC) program, the National Research Council's Industrial Research Assistance Program (IRAP) and Transport Canada's Transportation Development Centre. Others having a complementary role are Environment Canada, Natural Resources Canada and relevant provincial agencies. For items b) and c) above, candidate innovation support agencies having an interest and a management or technical role include the Transportation Development Agency, Environment Canada and Natural Resources Canada in addition to relevant provincial agencies (20).

7. CONCLUSIONS

Already, the EPA rulemaking has caused an economic impact and response from the Canadian railway sector (in the form of the RAC intervention with the EPA. The economic impact is in the form of the assignment of staff time, travel and communication costs to understand and discuss the contents of the Rulemaking. The magnitudes are difficult to quantify but are estimated to be several person-years and several hundreds of thousands of dollars per year.

In the absence of any Canadian equivalent, the EPA standards are the technical reference for any Canada-based manufacturer, re-manufacturer, overhaul facility, parts supplier or designer. However, perhaps the most significant impact of the EPA rulemaking for the Canadian railway sector is that it raises the question as to whether a Canadian equivalent should be promulgated.

Of the 3,328 locomotives in operation in Canada at the end of 1997, an estimated 2,000 will be retained in service over the next 10 to 15 years. The new locomotives purchased from the OEMs during this period are expected to meet Tier 1 and Tier 2 emissions standards. Modifying the older locomotives when re-manufactured to meet the equivalent of Tier 0 standards would lower the NOx, PM and HC emissions in line with those legislated in the U.S.A. This step may increase the CO_2 emissions depending on the retrofit technology used. The incentives for the railways would be to keep the asset value of older locomotives abreast of U.S. levels and to maintain their environmentally acceptable image in the public's eyes. To offset the resulting financial burden for the operating railways, the possibility of some form of tax rebate and other environment-based incentives would seem appropriate.

Pressure is mounting for all emissions-producing sectors to take action to reduce stress on the atmosphere. The Railway Association of Canada maintains that voluntary compliance is the most effective strategy in Canada (21). However, the railway emission problem affects a multiplicity of constituents and jurisdictions. The resolution is paced by political will, legislated compliance standards, enabling technology and economic viability. It is hoped that these four factors can be harmonized and emissions-reducing tactics can be implemented in a coordinated fashion.

8. RECOMMENDATIONS

The promulgation of the EPA rulemaking is a spur to advancing the technological frontier of locomotive and diesel engine design in North America. It is also a reference for the railways and government environmental authorities to examine locomotive emissions levels for the Canadian context. The recommendations emanating from this study are:

a) that the Canadian railways, manufacturers and equipment suppliers take advantage of this event and actively participate in the North American market created by the EPA requirements;

b) that governmental innovation support agencies consider support for new technology that could be developed and deployed accordingly. Included with this would be the testing and evaluation of low carbon-intense alternative fuels such as natural gas. This effort could be encompassed within a well-coordinated railway-led industry-government *Emissions Reduction Development Program* cooperative effort (as discussed in Section 5 herein);

c) that a more detailed study be made to quantify the reduction in NOx, PM and HC emissions over the next 10 to 15 years if the 2,000 older locomotives in the Canadian fleet were to be re-manufactured to the equivalent of EPA Tier 0 standards. This data plus data from the emissions profile of the new locomotives meeting Tier 1 and Tier 2 would be analyzed vis-à-vis the target levels in the voluntary compliance agreement between the RAC and Environment Canada; and

d) that an examination be made of the various forms of tax rebate and other environment-based incentives that could be introduced to offset the financial burden for the Canadian operating railways to introduce technology to reduce locomotive emissions harmful to the environment.

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Information from the Internet

There is considerable information now available electronically from a number of sites on the Internet and World Wide Web pertaining directly or indirectly to diesel engine emissions and their application in railway locomotives. The principal source is 'dieselNet', which can be accessed electronically at *http://www.deiselnet.com* . Some 3,000 pages of information were scanned electronically. Of note is that no information or technical papers emanating from Canadian sources were found. The preponderance of references originated in the U.S.A. with the remaining few from Europe (primarily Germany) and Japan. Of the 3,000 pages, approximately 1,600 were printed out and could be referenced by contacting the library of the Transportation Development Centre. The pages are filed under the following generic and specific titles:

Bibliographic Survey of Diesel Locomotive Emissions Reduction

(prepared by Dr. Eric Archambault, bibliometrist, for Peter Eggleton)

Volume I: Governmental Organizations and NGO Aspects

Volume II: Commercial Aspects

Volume III: R&D Aspects

Volume IV: Diverse Aspects including "dieselNet'

INFORMATION WORKSHOPS ATTENDED

In the course of undertaking the impact analysis, three workshops were attended in spring 1999 by the author, wherein there were specific sessions on the EPA rulemaking on locomotive emissions standards and their implications for the railway sector. The author appreciated the insights provided by the presentations and documentation available at the following workshops attended:

Date	Place	Event	Convened by
April 7	Washington D.C.	EPA Locomotive Workshop	U.S. Environmental Protection Agency
April 24-28	Columbus, Indiana	Internal Combustion Engine Conference	American Society of Mechanical Engineers
June 21-23	Winnipeg	Railways and the Environment	Environment Canada

APPENDIX A: Particulars of Canadian Railways and Locomotive Fleet during 1997

The particulars characterizing the Canadian operating railways in 1997 include:
(Source: *1998 Railway Trends,* Railway Association of Canada)

Number of Railways:	two Class I, 42 short and regional lines and six passenger and commuter railways.
Total Employees:	46,174
Locomotives:	3,328
Freight Cars:	112,136
Track Length:	50,684 kilometres
Revenue haulage:	304 billion tonne-kilometres
Intercity Passengers:	4 million
Commuter Passengers:	42 million
Fuel Consumed:	2.15 billion litres
Specific Fuel Consumption:	7.10 litres per net tonne-kilometre
Gross Revenues:	$7.728 billion (equiv. to 2.35 cents/rev tonne km)
Fuel and Property Taxes:	$459 million

Tables A-1 and A-2 contain data on the locomotives (by type and manufacturer) which were in service during 1997 on Canadian railways. Of the 3,328 locomotives in the current fleet, it is estimated that 2000 will be retained in service over the next 10 to 15 years. As regard which locomotives could be candidates for further re-manufacturing (and possible upgrading to Tier 0), the following breakdown is provided (15):

4-Axle Switchers - 191 in service, of which 75% will be used for more than 10 years. Most built before 1987 having 2-stroke engines;

4-Axle Line-haul - 1,150 in service, of which 53% will be retained for 10 years.
Mostly built between 1954 and 1987. Medium horsepower;

6-Axle Line-haul - 1,878 in service, of which 63% will be retained for 10 years.
Mostly built between 1965 and 1986. Nominally 3000 hp.

The economic decision regarding the type of emissions compliance action to opt for could be along the following lines:

Less than 12 years old - re-manufacture according to OEM recommendation
Between 13-20 years old - technology modification
Mid-life 21-30 years old - re-manufacture with new engine or existing engine
Between 31-40 years old - recommend unit be retired

Table A-1: Locomotives in Main Line and Branch Line Operations, 1997

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA RAIL	B. C. RAIL	GO TRANSIT	OTHER
GM/EMD	20V-645E3	3,200		6						6
	16V-710G3B	4,300	'96	139	139					
	16V-710G3B	4,000	'95	26	26					
	16V-710G3	3,800	'85-89	69	63	6				
	12V-710G3 or 710G3A	3,000	'88-'95	50					45	5
	16V-645F3B	3,600	'85-'94	66	60					6
	16V-645E3B	3,000	'85-'87	157		134		23		
	16V-645E3C	3,000		59			59			
	16V-645E3M	3,000	'88	25		25				
	16V-645E3	3,000	'66-'80	1,270	640	575				55
	16V-645D3A	2,250	'64-'66	48		18				30
	16V-645D3	2,250	'63	2		2				
	CAT 3516	2,075	'94	4		1				3
SUBTOTAL				1,921	928	761	59	23	45	105
MLW or BBD	16V-251F	3,700	'70-'84	29			29			
	16V-251F	3,000	'69-'82	7	6					1
	16V-251E	3,000	'67-'76	26						26
	16V-251B	2,400	'63-'66	23		16				7
	16V-251C	2,500	'64-'66							1
	CAT 3608	3,100	'88	1		1				
SUB-TOTAL				86	6	17	29	0	0	35
GE	16V-7FDL-16	4,400	'94-'95	291	103	184		4		
	16V-7FDL-16	4,000	'90-'94	109	80			26		3
	16V-FDL16	3,600	'80	16				15		1
	12V-7FDL12	2,250	'89-'90	3						3
	12V-FDL12	3,000	'79	0						
SUBTOTAL				419	183	184	0	45	0	7
BUDD-RDC	DD 6-110	550	'55-'58	21			6	9		6
TOTAL MAIN LINE & BRANCH LINE				2,447	1,117	962	94	77	45	153

Source: *Locomotive Emissions Monitoring Program - Reporting Years 1996 and 1997* - compiled and published jointly by Environment Canada and Railway Association of Canada)

Table A-2: Locomotives in Yard and Switching Operations, 1997

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA RAIL	B.C. RAIL	GO TRANSIT	OTHER
GM/EMD	16V-645E	2,000	'71-'75,'86	301	110	147				44
	16V-645C	1,800	'54-'67	259	242		11			6
	16V-645C	1,750	'75-'81	208		208				
	16V-645B/C	1,500	'81-'94	12		11				1
	16V-645D	1,500	'52	2						2
	16V-567C	1,750	'51-'63	82		1				81
	16V-567B	1,500	'51-'52,'78	17		1				16
	12V-645E	1,500	'71-'80	10						10
	12V-645C	1,350	'87-'89	8	8					
	12V-645C	1,200	'81-'85	88	56	32				
	12V-567C	1,200	'55-'60	121	69	34				18
	8V-645E	1,000	'66-'67	2			2			
	8V-645C	1,000	'67-'69	0						
	8V-567C	900	'51-'64	18	1	2				15
	8V-567B	800	'51-'54	4						4
SUBTOTAL				1,132	486	436	13	0	0	197
MLW	12V-251C3	2,000	'73-'81	60	35					25
	12V-251C	2,000	'64-'76	13				9		4
	12V-251C	1,800	'66	42		37		2		3
	12V-251B	1,800	'56-'65	41						41
	12V-251B	1,400	'59-'60	0						
	6I-251B/C	1,000	'59-'60	35						35
	6I-539	1,000	'48-'58	2						2
	CAT 12V-3512	2,000		27				27		
SUBTOTAL				220	35	37	0	38	0	110
TOTAL - YARD & SWITCHING:				1,352	521	473	13	38	0	307
GRAND TOTAL MAIN LINE, BRANCH LINE, YARD AND SWITCHING:				3,799	1,638	1,435	107	115	45	460

(Source: *Locomotive Emissions Monitoring Program - Reporting Years 1996 and 1997* - compiled and published jointly by Environment Canada and Railway Association of Canada)

APPENDIX B: Summary of Provisions of Part 92 of the EPA Rulemaking

The regulation's provisions are contained in a 100-page document promulgated by EPA in April 1998. The provisions are quite detailed and are written in a combination of engineering handbook and legalism rather than descriptive style. They are contained in twelve subparts and four appendices, with each subpart containing a number of sections. Reading the document requires considerable commitment and persistence. An attempt below is made to extract the highlights from the document so as the reader of this report will be facilitated when having to refer to the full EPA document. The subparts and sections are summarized as follows:

Subpart A - General Provisions for Emission Regulations for Locomotives and Locomotive Engines

Section 92-1: Applicability

The emissions standards apply to freshly manufactured (new) locomotives and re-manufactured locomotives. The standards remain applicable throughout the useful life of a locomotive. The definition of 'useful life' is based on the expected 'average period to next re-manufacture'. EPA has set this period as either equivalent to:

a) 750,000 miles of operation or ten years (whichever is reached first): or
b) when a MW-hr meter reading of 7.5 times the rated horsepower occurs (if locomotive is equipped with a MW-hr meter throughout its operations).

The emission standards apply to all locomotives except:

- Locomotives manufactured before 1973;
- Passenger locomotives manufactured before 2002;
- Historic steam locomotives;
- Locomotives powered by engines less than 750 KW (1006 hp);
- Re-powered locomotives and switchers using certified non-road engines;
- Tier 0 locomotives owned and operated by small businesses (<1,500 staff);
- Exported locomotives;
- Manufacturer-owned or re-manufacturer-owned locomotives;
- Locomotives used for display, testing or other development work (including testing in revenue service);
- National security actions; and
- Canadian and Mexican locomotives used in border traffic and incidental forays in the U.S.A.

Sections 92.2 through 92.6: General Provisions

These sections contain comprehensive listings of definitions (§92.2) and abbreviations (§92.3) used in the rulemaking, plus listings of applicable test methods (§92.5) issued by the Society of Automotive Engineers (SAE) and American Society of Testing and Materials (ASTM). In addition, statements are included on how the EPA will protect commercial-in-confidence information (§92.4) and the regulatory structure (§92.6). Of note vis-à-vis the latter, is that the regulation only applies at the point at which a locomotive or locomotive engine becomes 'new', that is, either as a result of being freshly manufactured or re-manufactured to either Tier 0, 1 or 2 standards (depending on the date of its original manufacture).

Section 92.7: General Standards

This section deals with non-engine devices on the locomotive such as those to minimize the escape of fuel vapors when locomotives are being refueled, operating at altitudes up to 7000 feet above sea level and shut down. Also stated is that locomotives and locomotive engines may not be equipped with 'defeat devices' such as Auxiliary Emission Control Devices or similar control features that reduce the effectiveness of the emission control system and causes in-use emissions to be higher than those measured under test conditions.

Section 92.8: Emission Standards

The emissions are measured over two steady-state test cycles that represent two different types of service including the *line-haul* and *switch* locomotives. The duty cycles include different weighting factors for each of the 8 throttle notch modes, which are used to operate locomotive engines at different power levels, as well as for idle and dynamic brake modes. The switch operation involves much time in idle and low power notches, whereas the line-haul operation is characterized by a much higher percentage of time in the high power notches, especially notch 8.

A dual cycle approach has been adopted in the regulation, i.e., all locomotives are required to comply with both the line-haul and switch duty cycle standards, regardless of intended usage. The smoke opacity standards are listed in Table B-1. The emission standards and current locomotive emission levels are listed on Tables B-2 and B-3.

Table B-1 Smoke Standards for Locomotives, (percent opacity - normalized)

	Steady-state	30-sec peak	3-sec peak
Tier 0	30	40	50
Tier 1	25	40	50
Tier 2	20	40	50

Table B-2 Emission Standards for Locomotives, g/bhp-hr

	HC*	CO	NOx	PM
Tier 0 (1973 - 2001)				
Line-haul	1.0	5.0	9.5	0.60
Switch	2.1	8.0	14.0	0.72
Tier 1 (2002 - 2004)				
Line-haul	0.55	2.2	7.4	0.45
Switch	1.2	2.5	11.0	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.20
Switch	0.6	2.4	8.1	0.24
Current Estimated Locomotive Emission Rates (1997)				
Line-haul	0.5	1.5	13.5	0.34
Switch	1.1	2.4	19.8	0.41
* - *HC standard is in the form of THC for diesel engines*				

The above total hydrocarbon (THC) standards refer to all locomotives and locomotive engines not fueled by alcohol or natural gas (for which total hydrocarbon equivalent standards apply). Of note is that allowance is made for alternate standards for CO and PM to be used by manufacturers or re-manufacturers (for which both emissions must be complied with) as shown in Table B-3.

Table B-3 Alternate CO and PM Standards (gm/bhp-hr)

	CO	PM	CO	PM
	Line-haul Cycle		**Switcher Cycle**	
Tier 0	10.0	0.30	12.0	0.36
Tier 1	10.0	0.22	12.0	0.27
Tier 2	10.0	0.10	12.0	0.12

Sections 92.9 and 92.10: Compliance with Emissions Standards and Warranties

This section concerns the procedure by which a manufacturer or re-manufacturer obtains 'Certification', that is, the process to apply for and obtain certificates of conformity from EPA that allow the OEM manufacturer or re-manufacturer to introduce into commerce new locomotives and/or new locomotive engines for sale or use in the USA. In order to obtain certificates, manufacturers shall demonstrate compliance based on emission data measured using procedures specified in Subpart

B - Test Procedures of the Rulemaking. The locomotives used for the compliance testing must be low mileage units and the engines must have low hours. The emission levels obtained from the new locomotives and engines must endure over their useful life which, if equipped with MW-hr meters is 7.50 times the rated horsepower, or 750,000 miles or ten years (whichever is reached first).

Warranties here pertain to the obligation on the part of the manufacturer or re-manufacturer that the locomotive and its engine shall not exceed the emission standards for at least the first third of the full useful life. The application for EPA certification must include the manufacturer's warranty, in this regard.

Sections 92.11 and 92.12: Compliance with Emissions Standards in Extraordinary Circumstances and Interim Provisions

These sections attempt to attend to problems associated with the envisaged permutations and combinations of design features and circumstances regarding the manufacture or re-manufacture of differing locomotive models to comply with Tier 0, Tier 1 or Tier 2 standards levels. They also attempt to block any attempt by manufacturers, re-manufacturers or operating railways to avoid compliance. The provisions herein might prove to be well-referenced in the event that the manufacturers are not able to develop technology in time to comply with the EPA standards. One provision that may prove to be controversial is the requirement of a manufacturer to 'devise a certified re-manufacturing system' (aimed at Tier 0 standards level) to be available for use where:

(i) the total cost to the owner and user of the locomotive (including initial hardware, increased fuel consumption and increased maintenance costs) during the useful life of the locomotive is less than US $220,000;

(ii) the initial hardware costs are reasonably related to the technology included in the re-manufacturing system and are less than US $50,000 for locomotives with 2-stroke engines and 4-stroke engines equipped with split cooling systems (or US $125,000 for locomotives with 4-stroke engines not equipped with split cooling systems);

(iii) the system will not increase fuel consumption by more than 3 percent;

(iv) the re-manufactured locomotive will have reliability throughout its useful life that is similar to the reliability had it been re-manufactured without the certified re-manufacture system.

Subpart B - Test Procedures

Sections 92.101 and 92.102: Applicability, Definitions and Abbreviations

This subpart designates the tests to obtain data as a basis for EPA certification. The test procedures cover gaseous emission, particulate mission and smoke density. They are intended to be performed by a range of constituents, such as the EPA, manufacturers, re-manufacturers, railways (and other owners and operators of locomotives) and designated testing laboratories.

Sections 92.103 through 92.132: Test Procedures and Equipment Requirements

These sections contain extensive and detailed instructions regarding the procedures for exhaust emission tests of locomotives and locomotive engines so as to obtain EPA certification. The procedures that are specified, including the instrumentation required, in these sections are intended to measure brake-specific mass emissions HC, NO_x, PM, CO, CO_2 and smoke in a manner representative of a typical operating cycle at ambient conditions ranging in temperature from 45 to 105 degrees Fahrenheit (7 to 41 degrees Celcius) and in atmospheric pressure from 31 to 26 inches of Hg (sea level to 7000 feet altitude). Variations in the procedures are included to accommodate fuels other than petroleum diesel such as natural gas, methanol or mixed fuels. To accommodate the wide range of additives in common use according to the preferences of different railways, the diesel fuel used in the tests may include nonmetallic additives such as: cetane improver, metal deactivator, antioxidant, dehazer, antirust, pour depressant, dye, dispersant and biocide.

Extensive provision are included to detail the exhaust gas and particulate sampling and analytical system, with particular reference to the design and calibration of the gas probe, dilution tunnel and related analyzer instrumentation. Also included are the pre-test and test procedures for the samplings, the calculations to be undertaken and the weighting factors to be applied. An unresolved issue (raised in various workshops by testing organizations) is the handling of NO_x correction factors for temperature and humidity.

Subpart C - Certification Procedures

Sections 92-201 to 92-207: Applicability, Definitions and Contents of Application for Certification

Described in these sections are the requirements and procedures to be undertaken by manufacturers and re-manufacturers to obtain EPA Certificates of Conformity for any locomotives and locomotive engines complying with Tier 0, Tier 1 or Tier 2 emissions standards. Of note is that a separate application must be submitted to EPA for each engine family. The application must be signed by the authorized representative of the manufacturer or re-manufacturer. The application must contain a complete description of the engine and the locomotive, with particular emphasis on how the emissions control system operates. To be included are detailed descriptions of the emission control components, injection timing for each notch power setting and all related interdependent functions (such as, inter alia: coolant temperature, fuel characteristics and auxiliary emission control devices). The application must also contain a description of the test equipment, the fuel used and all test data.

Ancillary information to be included with the application are, inter alia: the intended useful life, the intended deterioration factors, an unconditional statement certifying that the engine and locomotive meet all requirements of this part of the U.S. Clean Air Act. The application is also to include the U.S. production information for each configuration.

To facilitate the certification application process, the EPA is developing electronic Locomotive Engine Templates. These can be downloaded from the website of the EPA's Office of Mobile Sources Engine Certification Information Center at *http://www.epa.gov/oms/certdata.htm* using *FileMaker Pro* software. In advance of submitting a full, formal, application for certification, a manufacturer or re-manufacturer can ask the EPA to review the draft of all or part of the intended application. A response back from EPA within 90 days is targeted.

Sections 92-208 to 92-210: Awarding and Amending Certification

These sections contain the legal basis for the award of a Certificate of Conformity as well as the litigative actions that could be taken by the EPA Administrator if manufacturers or re-manufacturers submit false or inaccurate information in their applications or undertake questionable tactics. Allowed for if the direct participation of EPA staff members in the testing procedures and, as well, the repeating of tests to verify continuity.

Sections 92-211: Emission-related Maintenance Instructions for Purchasers

The EPA puts the onus on the ultimate purchase or owner for the adequate maintenance of locomotives to meet the emission standards throughout their useful life. Similarly, the EPA puts the onus on the manufacturer or re-manufacturer to furnish, or cause to be furnished, the ultimate owner with written instructions for the proper maintenance and use of the locomotive, or locomotive engine, as are reasonable and necessary to assure the proper functioning of the emissions control system.

To avoid certain monopolistic practices in the past by manufacturers, the manufacturer or re-manufacturer must provide in boldface type on the first page of the written maintenance instructions notice that maintenance, replacement or repair of the emission control devices and systems may be performed by any locomotive or locomotive engine repair establishment or individual. Concomitantly, the instructions cannot include any condition that the ultimate purchaser or owner is restricted to using any component or service establishment which is identified by brand, trade or corporate name. However, the EPA Administrator can waive any of the above restrictions if deemed in the public interest.

Sections 92-212 to 92-216: Labeling, Maintaining Records and Hearings

Each new or re-manufactured locomotive complying with EPA standards must a label permanently affixed to the locomotive and to its engine. Section 92-212 contains the information to be provided on the label.

Sections 92-213 to 92-215 contain the provisions regarding EPA's monitoring of locomotive and engine identification numbers of series production of families of units. This is intended both as a verification tool to EPA to be assured that proper engine records are being maintained as well as the basis for EPA deciding to, themselves, conduct emission tests on up to five units per model per year of a production run. Also contained in the provisions is the 'right of entry' by an EPA Enforcement Officer to the manufacturer's premises. Section 92-216 contains the procedures of a legal nature regarding hearings and appeals pertaining to disputes between the EPA and manufacturers and re-manufacturers.

Subpart D - Certification Averaging, Banking and Trading Provisions

Sections 92-301 to 92-310: Applicability, Calculations and Records

These sections cover the provisions and procedures for a manufacturer or re-manufacturer having a locomotive and/or engine design meeting Tier 0, Tier 1 or Tier 2 to participate in a certification averaging, banking and trading program for NO_x and PM emissions. The program does not cover HC, CO or smoke emissions. The provisions apply to the 1999 model year or later. Locomotives and engines exported from the USA may not be included in the program.

Averaging involves the generation of credits by a manufacturer or re-manufacturer from an engine family exhibiting emission levels below the Tier level to which it is certified. The credits can then be used by the same manufacturer or re-manufacturer in the same calendar year for averaging to offset an emission exceedance during certification of a specific engine family.

Banking involves the generation of credits by a manufacture or re-manufacturer in a given calendar year for use in a subsequent model year. The actual credits can only be banked after the end of the calendar year and after EPA has reviewed the manufacturer's end-of-year reports.

Trading involves the sale of banked credits for use in certification of new locomotives and new locomotive engines. A variation on trading is credit transfer in which control of credits is conveyed from owner to manufacturer or vice-versa at time of manufacture or re-manufacture.

Participation in the averaging, banking and trading program requires attention to record keeping, labeling, reporting and related administrative support. It appears

unlikely that organizations outside of the U.S.A.(such as Canadian railways or re-manufacturers) could be participants.

Subpart E - Emission-Related Defect Reporting Requirements, Voluntary Emission Recall Program

Sections 92-401 to 92-408: Applicability and Reporting Requirements

These sections contain the provisions wherein a manufacturer or re-manufacturer must file with EPA a defect information report whenever it determines, in accordance with procedures it established to identify either safety-related or performance defects, (or based on other information) that a specific emission-related defect exists in ten or more locomotives or engines. The report can be the basis for a voluntary emissions recall campaign as long as EPA is informed regarding remedial action. Reports are to be retained for not less than 8 years following manufacture.

Subpart F - Manufacturer and Re-manufacturer Production Line Testing and Audit

Sections 92-501 to 92-510: Applicability, Test Procedures and Reporting

The provisions of these sections apply to the EPA requirement that randomly chosen engines from a yearly production of new or re-manufactured locomotives and engines shall be tested for emissions compliance. The required sample size for an engine family is the lesser of five tests per model year or one percent of projected annual production (with a minimum sample size of an engine family of one test per model year provided that no engine tested fails to meet applicable emission standards). Each locomotive or locomotive engine will be selected from the end of the production line and have accumulated not more than 300 hours in service. Testing shall be performed throughout the entire model year to the extent possible. The EPA Enforcement Officers concerned are to be allowed 'right-of-entry and access' to the production facility and testing activity. Of note, is that allowance has been made in Section 92-504 whereby manufacturers shall locate their foreign (eg., Canadian) testing, manufacturing and re-manufacturing facilities in jurisdictions where local law does not prohibit EPA Enforcement Offices to operate.

The procedures for production line testing are identical to those described in Subpart B required to obtain certification. If one or more locomotives or engines fail a production line test, then the manufacturer or re-manufacturer must test two additional units from the next fifteen produced in that engine family, for each locomotive or locomotive engine that fails. The provisions include how the calculations and reporting of test results are to be performed vis-a-vis EPA and records are to be maintained.

Sections 92-511: Re-manufactured Locomotives: Installation Audit Requirements

This section addresses the auditing to ensure compliance of re-manufactured locomotives and locomotive engines. EPA puts the onus on the re-manufacturers to audit the re-manufacture of certified locomotives for conformity for proper components, component settings and component installations on randomly chosen locomotives in an engine family. This applies regardless of who actually supplied the parts and did the installation. The audits could be performed by the owners or operators of the locomotives on behalf of the re-manufacturer, but the re-manufacturer is responsible to EPA for the results of the audit. The initial sample size of each re-manufacturer is five percent of the re-manufacturer's annual sales per model year per installer, with a maximum number of ten per engine family per installer. A re-manufactured locomotive may accumulate no more that 10,000 miles prior to an audit.

Sections 92-512 to 92-517: Suspension and Revocation, Hearings and Appeals

The contents of these sections focus on the situations in which Certificates of Conformity are suspended or revoked due to failure of a production line test. The provisions allow for recourse via public hearings and appeals. Of note is that notwithstanding any claim of confidentiality made by the submitter, the EPA would make available to the public (during the hearings) any information submitted.

Subpart G - In-use Testing Program

Sections 92-601 to 92-607: Applicability, Testing Provisions and Reporting

The sections contain the provisions by which EPA annually identifies certified locomotive and engine families (and configurations within families) on which the manufacturer or re-manufacturer must conduct in-use emissions. For engine families of less than ten locomotives per year, no in-use testing will be required. The onus is on the manufacturers and re-manufacturers to perform the emissions testing and submit the data to EPA for review as to compliance. The test procedures shall be consistent with those described in Subpart B above. Locomotives are to be tested with their engines installed. The units should have accumulated between one-half and three-quarters of their useful life. A minimum of two locomotives per engine family per year are to be in-use tested. For each failing locomotive, two more locomotives shall be tested until the total number equals ten.

The test locomotive selected for testing must have a maintenance history that is representative of actual in-use conditions. The manufacturer may perform minimal set-to-specification maintenance on a test locomotive prior to in-use testing. The manufacturer or re-manufacturer must report the results to EPA within three months of completion of testing.

Subpart H - Recall Regulations

Sections 92-701 to 92-709: Voluntary Recall, Remedial Plans and Hearings

This Subpart deals with circumstances and litigation possibilities when EPA notifies a manufacturer or re-manufacturer that a substantial number of any class or category of locomotives or locomotive engines, although properly maintained and used, do not conform to the applicable emission regulations. The expectation is that the manufacturer or re-manufacturer would then either perform (without petition) a voluntary emissions recall or (following petition from EPA) submit a plan to remedy the nonconformity. If the provisions for submitting a remedial plan are not followed or the plan is not acceptable to EPA, public hearings could be resorted to. Section 92-709 contains an extensive description of the litigation procedure that could occur.

Subpart I - Importation of Non-conforming Locomotives and Locomotive Engines

Sections 92-801 to 92-805:

This Subpart deals with the case in which locomotives and locomotive engines that have not received a Certificate of Conformity are imported temporarily into the USA. The reasons for the temporary importation range from a U.S. company receiving a repair and overhaul contract, demonstration of new technology, testing, or temporary duty to handle an unexpected demand for motive power. The Subpart includes the instructions to be followed by which the EPA will approve the temporary importation of a non-conforming unit.

Subpart J - Exclusion and Exemption Provisions

Sections 92-901 to 92-905: Applicability, Exclusions and Export Exemptions

EPA has made allowances for the exemption of certain models of locomotives to meet emissions standards. Examples of those on the exclusion list are certain new locomotives, locomotives used in national security, locomotive manufactured or re-manufactured for export, display units, those used solely for the purpose of conducting a test program, locomotives being used for the purpose of developing a fundamentally new emission control technology related to either an alternate fuel or an after-treatment device and other special cases. Locomotives and their engines that are intended solely for export from the U.S.A. are exempt from EPA certification requirements but must be labeled or tagged (as having differing standards) on the outside of any container, on the locomotive and on the engine itself. Countries that have no standards whatsoever (such as is the case for Canada), are deemed to be a country having emissions standards which differ from EPA standards.

Subpart K - Requirements Applicable to Owners and Operators of Locomotives and Locomotive Engines

Sections 92-1001 to 92-1006: In-use Testing, Maintenance and Refueling

This Subpart describes the requirements of Class I railways and all other non-exempted owners and operators of locomotives and locomotive engines in the USA. Each Class I freight railway, beginning January 2005 will be required to test a sample of locomotives in use in its fleet. A railway's fleet is defined to include both the locomotives it owns and the ones it leases. The number of locomotives to be tested shall be 0.15 percent of the average number of locomotives in the fleet during the last calendar year. However, the maximum number per year per railway will not exceed five. Beginning January 2016, the number of locomotives to be tested by railways with 500 or more units shall be 0.10 percent of the average number in the fleet during the previous calendar year. The number of units to be tested in the service of those non-Class I railways subject to EPA provisions shall not exceed two per railway (or other entity) per year.

Locomotives to be tested are selected randomly, but representative of those from each manufacturer or re-manufacturer and from each Tier level (eg., Tier 0, Tier 1 and Tier 2) in proportion of their numbers in the fleet. The railways are required to submit their test reports to EPA within 30 days of completion of the in-use testing. EPA allows equivalent emission data collected for other purposes to be submitted in lieu of in-use testing. The owner of the locomotives is required to maintain records of all maintenance and repairs that could reasonably affect the emission performance of any locomotive or locomotive engine. The onus is on the railway to supply the units for testing at a place and schedule mutually agreeable with the EPA.

Related to this in-use testing is the requirement that refueling equipment used by a locomotive operator for locomotives fueled with a volatile fuel shall be designed in such a manner so as not to render inoperative or reduce the effectiveness of the controls on the locomotive that are intended to minimize the escape of fuel vapours. Also, hoses used to refuel gaseous fueled locomotives shall not be designed to be bled or vented to the atmosphere under normal operating conditions.

Subpart L - General Prohibited Acts and Enforcement Provisions

Sections 92-1101 to 92-1108: Prohibited Acts, Enforcement Provisions, Penalties, Warranty and In-use Compliance

These sections apply to all manufacturers, re-manufacturers, owners and operators of locomotive and locomotive engines subject to EPA provisions.
They list a variety of prohibited actions primarily those concerning the supply and use of non-conforming locomotives supplied after the EPA rulemaking came into force. As well, prohibited acts, inter alia, include the falsifying of test data, rendering emission devices inactive, bypassed or defeated, failure to undertake necessary maintenance and repairs, failure to properly label or tag a certified locomotive and requiring use of a manufacturer's components or services during repair. The EPA Administrator is empowered to enter facilities and premises for the purposes of inspecting or observing any activity of a suspect nature. The penalties for undertaking prohibited acts are detailed as are the fines which range from U.S. $2,500 to $200,000.

Subpart L concludes with a reminder that the manufacturer or re-manufacturer is obligated to provide a warranty to the ultimate purchaser of each locomotive and locomotive engine that it has been designed, built and equipped so as to conform at the time of sale (or time of return to service following remanufacture) to the EPA provisions, and is free from defects in materials and workmanship which cause such locomotive or locomotive engine to fail to conform with applicable regulations for its warranty period. Similarly, the owner of any locomotive or locomotive engine so warranted is responsible for the proper maintenance of the unit. Proper maintenance includes replacement and/or service, as needed, at the owner's expense at a service establishment or facility of the owner's choosing, of all parts, items or devices which were in general use with locomotives and locomotive engines prior to 1999. For diesel engines, this would generally include replacement or cleaning of the fuel delivery and injection system.

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