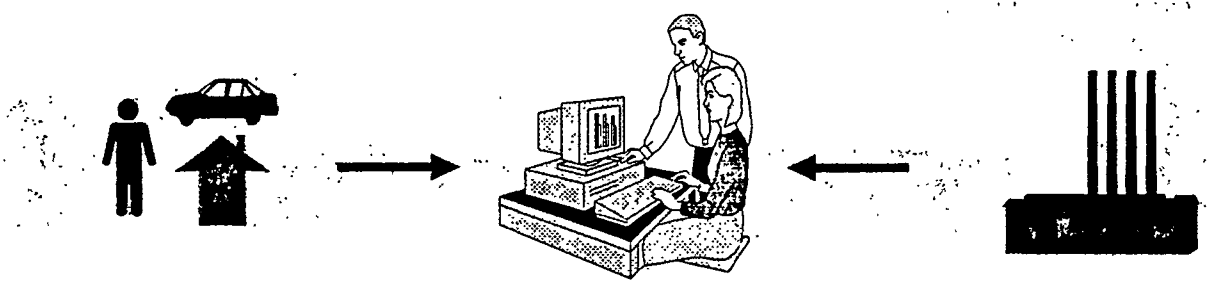
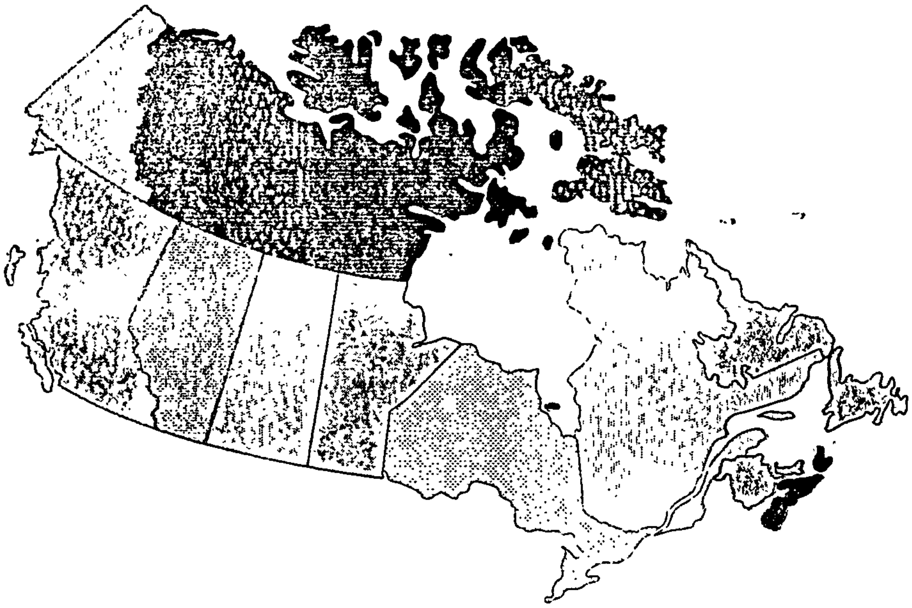
# METHODS MANUAL FOR ESTIMATING EMISSIONS OF COMMON AIR CONTAMINANTS IN CANADA





Prepared for :
Environment Canada
Conservation & Protection
Regulatory Affairs &
Program Integration Branch

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May, 1991

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# METHODS MANUAL FOR ESTIMATING EMISSIONS OF AIR CONTAMINANTS FROM CANADIAN SOURCES

Prepared for
Environment Canada

By
ORTECH International

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# Methods Manual for Estimating Emissions of Common Air Contaminants from Canadian Sources

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Report No. P.89-50-6299/FG

April 18, 1991

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# PREFACE

This manual presents sources of information and methods that may be used for compiling regional anthropogenic emission inventories of common air pollutants for major Canadian point, area and open sources at the process resolution. It is intended to assist government agency and other users by describing conventional methods used in previous Environment Canada emission inventories and recommending approaches that can be readily implemented in preparing future inventories. Relevant emission points are identified with appropriate codes and applicable sources of base quantity, emission factor and other information are provided to derive emissions of particulate matter, $SO_2$, $NO_x$, HC and CO for the following major source categories:

A - Industrial Processes
B - Stationary Fuel Combustion
C - Waste Incineration
D - Transportation
E - Open Sources

The manual is arranged in coded and dated chapters, corresponding to specific contributing sectors within the above categories in order to facilitate insertion of new or additional material.

## PREFACE

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# 1. INTRODUCTION

For several years, the Inventory Management Division of Environment Canada has compiled, maintained and updated emission inventories of various air contaminants. This knowledge and information base on emission sources assists in defining environmental strategies and priorities, provides documentation to evaluate the effectiveness of emission control measures and provides data for source/receptor model development, exposure assessments and other research activities. On the basis of Canadian total anthropogenic emission estimates (10 provinces) for the 1985 NAPAP inventory (U.S. EPA 1989 and Environment Canada 1990), the following annual emissions and contributions by general source categories were derived:

| General Category Contribution | Annual Emissions (Tonnes) | | | | |
|---|---|---|---|---|---|
| | Particulate | $SO_2$ | $NO_x$ | HC | CO |
| | 1,709,484 | 3,686,609 | 1,959,492 | 2,315,754 | 10,780,747 |
| Indust./Mfg. Proc. (%) | 53.2 | 69.8 | 4.5 | 25.0 | 7.2 |
| Fuel Comb. (%) | 22.1 | 27.6 | 30.3 | 9.6 | 11.7 |
| Transportation (%) | 6.5 | 2.6 | 63.9 | 41.5 | 66.4 |
| Incineration (%) | 2.2 | 0.1 | 0.4 | 1.9 | 4.0 |
| Other Sources (%) | 16.0 | 0 | 0.9 | 22.1 | 10.7 |

It can be seen that the contributions between major source categories vary significantly by the pollutant type and that industrial sources account for most particulate and $SO_2$ emissions, while area sources (e.g., transportation category) represent a substantial fraction of $NO_x$, HC and CO emissions. In many instances, these emissions have been approximated by the use of emission factors and material balances, due to the rather limited amount of available stack test information. On the other hand, measurement data are often used in deriving annual emission estimates for some of the significant point source contributors ($SO_2$ for example). It is somewhat difficult to compare Canadian and U.S. or other regional source contributions due to differences in methods used, the means of acquiring data, the availability of statistical or individual source data and certain differences in sector (source classification) definitions. Major differences occur in the methods by which industrial fuel combustion and some mobile source emissions are calculated. Nevertheless, as approaches become more developed, standardized and verified, inventories can be compiled with more certainty.

The importance of emission inventories and demands for accuracy is greatly increasing, especially in cases where inventory data are required for developing control strategies. Similarly, reliable inventory data are needed to address major environmental issues such as: oxidant formation, acid precipitation, upper atmospheric modifications and air toxics. For example, accurate information on emissions of common air contaminants is required, since emissions of specific toxic components are sometimes determined from total particulate and total volatile organic compound emission compilations. Hence, appropriate methodology to accurately calculate emissions is of prime importance. In this regard. Environment Canada and U.S. EPA have undertaken studies to document methods for estimating emissions. Several reports or manuals have been or are being prepared to address methods for specific contaminants such as $SO_2$, $NO_x$ and VOC, as well as other pollutants. In addition, inventory working groups have formed to develop detailed sector-specific inventory approaches. The need now exists to consolidate and describe these methods with supporting information in a structural form such that the methods can be applied consistently in compiling future inventories. Method manuals are also required, since the preparation of national inventories is less of an exercise residing with a central body but is increasingly directed toward gathering of information by personnel involved directly with the emitting sources. The consolidation will also support the information requirements needed by end users of the emission estimates by providing additional background to the compilation approaches and greater meaning to the data.

## 2. STUDY SCOPE AND OBJECTIVES

The overall objective in preparing the manual is to summarize, consolidate and describe best-available inventory methods on a sector basis for review and guidance of users such as government agencies and possibly industries. It is recognized that inventories can be prepared in varying levels of detail and that the quality of estimated emissions will be regulated by the amount/quality of available information, time and resources. Accordingly, a reasonable level of detail and definition of information requirements is reflected in the manual in order for the methods to be readily implemented by the user.

The procedures to estimate emissions are known to be adequate for some sectors, but less advanced in some cases where appropriate data are lacking (e.g., confidential base quantities, unavailable in-house measurement data). The major objective of this manual is to consolidate the best methods from published literature and previous Environment Canada/EPA reports. Unpublished methods or information that can be made available from provincial contacts and inventory working groups (e.g., Environment Canada/industry) have been incorporated where appropriate. It is beyond the scope and scheduling of this study to procure direct information from industries or to develop emission factors/algorithms from fundamental information. Where data are lacking for sources considered to be important, preferred and alternative inventory methods are proposed for updating techniques to achieve the best inventory data. Where methods are thought to still need further development, recommendations to acquire appropriate data are made in the manual. The methods described are primarily intended for users that prepare inventories on a larger geographical basis, rather than for specific sites since the methods are not intended to be a guide for preparing micro-inventories or environmental audits.

## 3. MANUAL ORGANIZATION

Important features of this manual are:

- it can be readily updated by page addition or replacement,
- it is organized to facilitate cross-referencing to Environment Canada's Residual Discharge Inventory System (RDIS) through the use of Standard Industrial Classification codes (SICs) and Source Classification Codes (SCCs).

It should be noted that while the U.S. EPA system of SCC codes is consistent with that used by Environment Canada, the SIC system used in the United States is quite different from that used in Canada. Only Canadian SIC codes have been used in this manual.

Each section of the manual is separately paginated and deals with an individual SIC or group of SICs. In this way, sections can be freely added or replaced with updated information. The sections are numbered using a letter followed by two numbers: A.37.1, for example. The following conventions are followed in assigning the identifiers:

| | | |
|---|---|---|
| Emission Category: | A | Industrial |
| | B | Stationary Fuel Combustion |
| | C | Incineration |
| | D | Transportation |
| | E | Open Source |
| First Number: | first two digits of the Standard Industrial Classification Codes (SIC) | |
| Second Number: | arbitrary sequence number distinguishing sections with the same first two digits in the SIC number | |

# 4. OVERVIEW OF INVENTORY TECHNIQUES

## 4.1 Inventory Purpose and Point/Area Source Distinction

An emission inventory is generally a comprehensive, accurate account of air pollutant emissions and associated data from sources within the inventory area over a specified time frame that can be used to determine the effect of emissions on ambient air quality. (U.S. EPA 1981) Environment Canada's Residual Discharge Inventory System (RDIS) is a computerized data base management system used to maintain data on major emission sources at the process resolution, using the point and area source approach. The data are compiled on a provincial and national basis and the information can also be compiled on other geographical resolutions. In this respect, data may normally be used for:

- establishing emission trends which may reflect economic activity, the influence of air pollution control legislation, etc.,
- dispersion and atmospheric chemistry modelling to define present and future air pollutant effects (e.g., acid deposition and oxidant formation),
- assessing present and future control strategy development,
- energy analysis, research purposes and information dissemination.

Furthermore, data in this present form, or in conjunction with other information on file, can be used to quantify emissions within jurisdictions, siting ambient monitoring stations or define emission attainment. However, these latter end uses are normally the responsibility of provincial regulatory agencies which generally maintain more detailed source characteristics in permit files or emission inventories. The purpose of the current emission compilations has been directed mainly toward defining annual emission trends in Canada, in order to characterize the effects of control strategies that are being implemented in the various provinces to reduce effects of air contaminants. Thus, consistency of methods in compiling emissions is an important consideration.

It can normally be expected that the accuracy and utility of the emission inventory will increase as a greater fraction of total emissions is included in the point source data file (U.S. EPA 1981). That is, data in the point source file are more detailed and reliable than the data maintained in the area source files. However, greater resources and manpower are required to update point source data. In most instances, major sources of the criteria pollutants have been accounted for in the Environment Canada point source inventory. In some cases, individual sources within the point source classification may not exceed a specified cut-off level (i.e., 100 tonnes per year of sulphur dioxide, for example), but have been designated as point sources in order to maintain record consistency. Alternatively, some individual sources within the area or mobile source classification (e.g., large industrial boilers, engines or mineral processing kilns) may have emissions which exceed this amount but, for purposes of the Environment Canada inventory, remain within the current area source designation, since these emissions result almost entirely from the fuels consumed which are accounted for in area stationary fuel combustion sectors. Similarly, some emission sources that exceed the cut-off level are, in certain instances, compiled as area sources since they are too numerous to be maintained on an individual point source basis using the present data collection logistics. Hence, point/area source distinctions or cut-off levels (and thus sources considered) can be expected to vary between federal and provincial inventories according to the intended application of the inventory data.

## 4.2 General Approaches Used to Obtain Emission Data or Methods

Information from various reports and documents has been consolidated in preparation of this methods manual. For example, methodologies used by

Environment Canada in preparing inventories, provincial methods/data and U.S. inventory procedures were reviewed and selected methodologies were incorporated in the manual. In general, emission and other associated data are procured by provincial agencies or federal government departments from replies to questionnaires sent to individual companies, by direct contact with companies or by data submitted by companies for regulatory purposes. In certain cases (Ontario, for example), data are obtained by regional offices and forwarded for centralized processing. Data may be in the form of actual emissions determined by the company (or association) or necessary information to permit the emission calculations to be done by officials of the regulatory agency. Although emissions are not normally compiled on a yearly basis, except for the strongest sources, the potential and capabilities for annual emission upgrading is available in each province.

Emissions may be derived for a given process or operation by one or more of the following methods:

- stack test or continuous emission monitoring results from surveys conducted by companies or government agencies that can be used for annual emission estimates in combination with production rates or operating days. Such results should be used in preference to other data if considered representative of normal operating conditions,
- a mass balance approach in which the atmospheric emission is determined from the difference between the amounts of total solvent or sulphur, for example, contained in feed materials and that contained in the products or process wastes. Mass balances are most appropriately applied to fuel sulphur contributions and mineral processing activities where sufficient data are available to derive average sulphur contents of process streams; hydrocarbon emission from solvent use are generally readily estimated by mass balance,
- emission factors where source test information is not available or material balances are not technically feasible. Emission factors can be used to estimate the rate at which a pollutant is released to the atmosphere as a result of some process activity. Average values which are used for a given source category may differ from actual

emissions for a specific facility and may be developed on the basis of source test or other data. A comprehensive list of emission factors has been developed by the U.S. EPA (U.S. EPA 1985 and 1987) and is upgraded as information becomes available. Emission factors also have been developed by Environment Canada for specific source categories. The values indicated in this manual are factors obtained from the most recent EPA publication, Environment Canada reports or derived for specific sources,

- emission factor estimates which may be determined from process knowledge or surmised using various assumptions of the operation.

In all cases, the influence of control devices should be considered (i.e., pollutant removal efficiency) where appropriate and a separate contribution of process emissions from fuel-use emissions should be derived where feasible.

The procedures recommended throughout this manual follow a consistent approach of data collection. It is logical and most appropriate to assume that provincial regulatory agencies should be primarily responsible for compiling point source emissions within their aerial jurisdictions (as has been done in the 1985 inventory) (Environment Canada 1990), and that area source emissions be compiled by federal government personnel. In practically all instances, it is suggested that both emission and necessary process data (e.g., sources considered, base quantities, sulphur contents of fuels, operating frequency, methods of calculating emissions, etc.) be procured directly from the major contributing sources at the process level (i.e., by questionnaire, telephone contact, review of permit data or other means). Should emission anomalies be identified (e.g., between similar sources or between years for the same source), further contact with the company is suggested to resolve or document reasons for differences. Although data collection procedures may be straightforward, the assessment of the adequacy of the collected data with regard to representativeness, completeness and accuracy can be demanding, especially when data are from sources which are large and complex or sources of fugitive emissions exist. In order to document emission trends and impacts of control strategies in Canada, it is recommended that both point and area source emissions be compiled or updated annually.

# 5. GLOSSARY

| Term | Definition |
|---|---|
| Activity Level | The process-level base quantity or rate relating the amount of fuel consumed, quantity of product manufactured in an industrial process, or some comparative measure within a given time period. |
| Air Pollutant | Any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air. |
| Area Source | Generally, small collective sources that are inventoried as a group such as:<br>any small residential, governmental, institutional, commercial, or industrial fuel combustion operations; onsite solid waste disposal facility; motor vehicles, aircraft, vessels, or other transportation facilities; or other miscellaneous sources. Other sources which are too numerous to inventory as point sources. |
| Common or Criteria Pollutant | Any air pollutant for which national ambient air quality objectives exist, including: sulfur dioxide, particulate matter, carbon monoxide, hydrocarbons, nitrogen dioxide, ozone, hydrogen fluoride and hydrogen sulphide. |
| Emission | The act of releasing or discharging air pollutants into the ambient air from any source. |

| Term | Definition |
|---|---|
| Emission Factor | An estimate of the rate at which a pollutant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. |
| Facility | An identifiable piece of process equipment. A stationary source is composed of one or more pollutant-emitting facilities. |
| Fossil Fuel | Natural gas, petroleum, coal, and any form of solid, liquid, or gaseous fuel derived from such material for the purpose of creating useful heat. |
| Fuel-Burning Equipment | Any furnace, boiler, apparatus, stack, and other unit used in the process of burning fuel for the primary purpose of producing heat or power by indirect heat transfer. |
| Fuel Evaporative Emissions | Vaporized fuel emitted into the atmosphere from the fuel system of a motor vehicle. |
| Fugitive Emissions | Those emissions which do not pass through a stack, chimney, vent, or other functionally equivalent opening. |
| Hydrocarbon | Any organic compound consisting predominantly of carbon and hydrogen. |
| Mobile Source | Including: light-duty gasoline powered vehicles; light-duty diesel powered vehicles; light-duty and heavy-duty gasoline powered trucks; heavy-duty diesel powered vehicles; gaseous fueled vehicles; motorcycles; aircraft; locomotives; in-board and out-board powered vessels; agricultural equipment; heavy-duty construction equipment; snow mobiles; small, general utility engines. |

| Term | Definition |
|---|---|
| Nitrogen Oxides | All oxides of nitrogen except nitrous oxide. |
| Particulate Matter | Any finely divided solid or liquid material, other than uncombined water. |
| Point Source | Any of the following stationary sources of air pollutants which emit, or have the potential to emit, 100 tonnes per year or more of any regulated pollutant. Fossil fuel-fired steam electric plants of more 250 million British thermal units per hour heat input, coal cleaning plants (with thermal dryers), kraft pulp mills, portland cement plants, primary zinc smelters, iron and steel mill plants, primary aluminum ore reduction plants, primary copper smelters, municipal incinerators capable of charging more than 250 tons of refuse per day, hydrofluoric, sulfuric, and nitric acid plants, petroleum refineries, lime plants, phosphate rock processing plants, coke oven batteries, sulfur recovery plants, carbon black plants (furnace process), primary lead smelters, fuel conversion plants, sintering plants, secondary metal production plants, chemical process plants, fossil-fuel boilers (or combination thereof) totaling more than 250 million British thermal units per hour heat input, petroleum storage and transfer ore processing plants, glass fiber processing plant, and charcoal production plants. |
| Sources | Any structure, building, facility, equipment, installation or operation (or combination thereof) which is located on one or more contiguous or adjacent properties and which is owned or operated by the same person (or by persons under common control). |

| Term | Definition |
|---|---|
| Source Classification Codes (SCC) | Code developed for inventory purposes giving specific identification of a source, and defining the units of activity level, and emission factors related to point or area source activity levels. Emissions may be calculated by multiplying the emission factor for each SCC and the activity level. |
| Stack | Any chimney flue, conduit, or duct arranged to conduct emissions to the ambient air. |
| Standard Industrial Classification (SIC) | The classification of establishments by type of activity in which (it is) engaged; for purposes of facilitating the collection, tabulation, presentation, and analysis of data relating to establishments. Classification of establishments by industry on a two-digit, a three-digit or a four-digit basis. |
| Stationary Source | Any structure, building, facility or installation which emits or may or may emit any regulated pollutant to air. |
| Volatile Organic Compounds (VOC) | Any compound containing carbon and hydrogen or containing carbon and hydrogen in combination with any other element which has a vapor pressure of 1.5 pounds per square inch absolute (77.6 mm.Hg) or greater under actual storage conditions. |
| Process | Any action, operation or treatment of materials, including handling and storage thereof, which may cause discharge of an air contaminant, or contaminants into the atmosphere, but excluding fuel burnings. |

| Term | Definition |
|---|---|
| Process Operation | Any chemical, industrial, or manufacturing operation including, but not limited to, heat transfer, fluid flow, evaporation, humidification, absorption, extraction, distillation, drying, mixing, classification, sedimentation, decantation, filtration, crystallization, centrifugation, disintegration and material handling. |
| Process Source | The last operation or process which produces an air contaminant resulting from (i) the separation of the air contaminant from the process material, or (ii) the conversion of constituents of the process material into air contaminants and which is not an air pollution abatement operation. |

## References

Environment Canada 1990. "Canadian Emissions Inventory of Common Air Contaminants (1985)". Environmental Protection Services Report EPS 5/AP/3.

U.S. Environmental Protection Agency (U.S. EPA) 1981. "Procedures for Emission Inventory Preparation - Volumes I to V". Reports EPA-450/4-81-026 a to e.

U.S. Environmental Protection Agency (U.S. EPA) 1985. "Compilation of Air Pollutant Emission Factors - AP-42" - including Updated Supplements.

U.S. Environmental Protection Agency (U.S. EPA) 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory". Report prepared by Radian Corp., NTIS PB 87-198735.

U.S. Environmental Protection Agency (U.S. EPA) 1989. "The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modellers Tapes", EPA-600/7-89-012a.

## A.06.1 COAL CLEANING (SIC 06300)

### a) General Description

The coal industry involves three major steps: mining and handling, coal cleaning and beneficiation, and transportation. Coal mining and handling is inventoried under SIC 06301. Coal transportation is inventoried under SIC 06302.

Coal cleaning is a process by which impurities such as sulfur, ash and rock are removed from coal to upgrade its value. Coal cleaning processes are categorized as either physical cleaning or chemical cleaning. Physical coal cleaning processes, the mechanical separation of coal from its contaminants using differences in density, are by far the major processes in use today. Chemical coal cleaning processes are not commercially practical and are, therefore, not included in this manual. (U.S. EPA 1985)

Emissions of particulate matter, $NO_x$, $SO_x$ and VOCs are inventoried for coal cleaning.

### b) Sector Description (U.S. EPA 1985, 1987)

The steps used in physical coal cleaning processes vary among coal cleaning plants but can generally be divided into four basic phases: initial preparation, fine coal processing, coarse coal processing, and final preparation.

In the initial preparation phase of coal cleaning, the raw coal is unloaded, stored, conveyed, crushed, and classified by screening into coarse and fine coal fractions. The size fractions are then conveyed to their respective cleaning processes. These processes are inventoried under materials handling (SIC 06301).

Fine coal processing and coarse coal processing use very similar operations and equipment to separate the contaminants. The primary differences are the severity of operating parameters. The majority of coal cleaning processes use upward currents or pulses of a fluid such as water to fluidize a bed of crushed coal and impurities. The lighter coal particles rise and are removed from the top of the bed. The heavier impurities are removed from the bottom. Coal cleaned in the wet processes then must be dried in the final preparation processes.

Final preparation processes are used to remove moisture from coal, thereby reducing freezing problems and weight, and raising the heating value. The first processing step is dewatering, in which a major portion of the water is removed by the use of screens, thickeners and cyclones. The second step is normally thermal drying, achieved by any one of three dryer types: fluidized bed, flash and multilouvered. In the fluidized bed dryer, the coal is suspended and dried above a perforated plate by rising hot gases. In the flash dryer, coal is fed into a stream of hot gases for instantaneous drying. The dried coal and wet gases are drawn up a drying column and into a cyclone for separation. In the multilouvered dryer, hot gases are passed through a falling curtain of coal. The coal is raised by flights of a specially designed conveyor. The second step may alternately involve drying using less complicated systems such as rotary dryers, when the coal separation processes have not involved wet separation processes.

The major source of emissions from the final preparation phase is the thermal dryer exhaust. This emission stream contains coal particles entrained in the drying gases, in addition to the standard products of coal combustion resulting from burning coal to generate the hot gases. The most common technologies used to control this source are venturi scrubbers and mist eliminators downstream from the product recovery cyclones. The particulate control efficiency of these technologies ranges from 98 to 99.9 percent. The venturi scrubbers also have an $NO_x$ removal efficiency of 10 to 25 percent, and an $SO_2$ removal efficiency ranging from 70 to 80 percent for low sulfur coals to 40 to 50 percent for high sulfur coals.

The following SCCs are used to code coal cleaning processes:

| | | |
|---|---|---|
| 3-05-010-01 | - | Fluidized Bed |
| 3-05-010-02 | - | Flash or Suspension |
| 3-05-010-03 | - | Multilouvered |
| 3-05-010-04 | - | Rotary |
| 3-05-010-05 | - | Cascade |
| 3-05-010-06 | - | Continuous Carrier |
| 3-05-010-07 | - | Screen |

### c) Inventory Approach

Coal cleaning operations are inventoried as point sources. Where available, the use of site-specific emission rates based on source testing is the preferred emission estimation method. Failing site specific data, emission factors based on the amount of coal dried are used.

### d) Preferred Emission Estimation Method

AP-42 (U.S. EPA 1985) outlines particulate emission factors with and without various control options for all three thermal coal dryers, with $SO_2$, $NO_x$ and VOC emission rates for fluidized bed dryers. This list of emission factors was expanded and revised for the 1985 NAPAP emissions inventory (U.S. EPA 1987) to include other drying processes and pollutants as appropriate.

Unless site-specific emission rates are available, the use of the NAPAP emission factors is recommended, with emissions control efficiencies from AP-42 on a site-specific basis. It should be noted that the $NO_x$ and VOC emission factors in U.S. EPA 1987 are after scrubber emission factors. All materials handling emissions associated with coal cleaning should be inventoried under SIC 06301.

### e) Activity Level

Activity levels, in tonnes coal dried, are best obtained on a point-by-point basis from the operator.

A list of operators, along with mine locations and some production information, is available in operator lists maintained by Energy Mines and Resources Canada (e.g., EMR 1979). It should be noted that production rates in this publication are for saleable coal (raw coal, clean coal and middling sales).

Another source of information is the Canadian Minerals Yearbook, which provides annual provincial coal production rates. Again, there is not distinction as to the type of coal (raw, clean or middling).

Finally, provincial ministries and mining associations may be able to supply further regional information.

Coal cleaning point sources currently listed in the Environment Canada residual discharge inventory system are listed in Section i).

## f) Alternative Emission Estimation Procedures

Coal cleaning operations may alternatively be inventoried as area sources.

In this case, a single emission factor must be selected for particulate, $NO_x$, $SO_x$ and VOCs. In the U.S., fluidized bed technology accounts for 75% of the dryers. Assuming this to be the case in Canada, emissions factors for SCC 3-05-010-01 in U.S. EPA (1987) would be applied to all coal cleaned.

## g) Temporal Variability

Seasonal, daily and hourly temporal factors for mining and rock quarrying in a report by The MEP Company and Ontario Research Foundation (1985) can be used for this sector.

## h) Geographical Apportionment

Data are available on a point basis if the preferred method is used. The alternate method provides information on a provincial basis.

## i) Point Source Establishments

Point sources currently on the Environment Canada Residual Discharge inventory system under SIC 06300 are:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Alberta | 480115 | Cardinal River Coals Ltd. | Hinton |
| | 480113 | Coleman Collieries Ltd. | not listed |
| | 480157 | Gregg River Resources Ltd. | Hinton |
| | 480143 | Luscar Sterco Ltd. | Edson |
| | 480116 | McIntyre Mines Ltd. | not listed |
| | 480158 | Obed Mountain Coal Co. Ltd. | Hinton |
| | 480159 | Smoky River Coal Ltd. | Grand Cache |

## References - Section A.06.1

Energy, Mines and Resources Canada, 1979. "Operators List 4. Coal Mines in Canada". Supply and Services Canada.

The MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.06.2 SALT PRODUCTION (SIC 06250)

### a) General Description

In Canada, salt is produced by mining, fine vacuum recovery and recovery from brine. Particulate matter is the only criteria pollutant of concern. Any $SO_x$, $NO_x$ and VOC emissions are associated with fuel combustion and are normally inventoried as part of industrial fuel combustion (SIC 56223).

### b) Process Description

Salt mining involves the removal of salt rock from underground by conventional methods, followed by crushing, screening and packaging.

Fine vacuum salt and recovery of salt from brine are the two other methods of production. In each case, the salt is passed through dryers and subsequently crushed and screened.

Drying, crushing, screening and material handling operations all generate particulate matter. Crushing operations typically use cyclones or filters for particulate matter emission control. Cyclones or scrubbers are usually used to control emissions from dryers.

The following SCCs may be used to inventory salt production:

| | |
|---|---|
| 3-05-021-01 | General (mining) |
| 3-05-021-02 | Granulation: Stack Dryer |
| 3-05-021-03 | Filtration: Vacuum Filter |
| 3-05-021-04 | Crushing |
| 3-05-021-05 | Screening |
| 3-05-021-06 | Conveying |

### c) Inventory Approach

Salt production operations are inventoried as point sources of particulate matter. The preferred method is to use source-specific emission data based on source testing and/or operating permits. However, if this data is not available, particulate matter emissions may be estimated using emission factors based on the tonnes of salt produced. Emissions of $SO_x$, $NO_x$ and VOC associated with fuel combustion (usually natural gas) in the dryer are normally inventoried as part of Industrial Fuel Combustion (SIC 56223). However, they may be inventoried as part of this sector using emission factors based on tonnes of salt handled.

### d) Preferred Emission Estimation Procedure

The controlled particulate matter emission factor for salt mining (1.35 kg/tonne of salt produced) developed by Environment Canada (Environment Canada 1983), is based on AP-42 (U.S. EPA 1985) controlled emission factors for stone quarrying and processing. Environment Canada (1983) uses a controlled particulate matter emission factor of 2.19 kg/tonne for the other two salt production methods. This emission factor, which was developed internally by Environment Canada, is equivalent to that used in the potash industry (SIC 06240).

### e) Activity Level

Statistics Canada produces an annual report on Non-Metal Mines (Catalogue No. 26-224), which includes a list of establishments and production data for salt mines. The Canada Minerals Yearbook is another potential source of production data. Lists of establishments and production data can also be obtained through federal or provincial ministries.

### f) Alternative Emission Estimation Procedures

Particulate matter emission factors for the various processes may also be based on emission factors directly from AP-42 (U.S. EPA 1985) and NAPAP (U.S. EPA 1987) for similar processes in stone quarrying/processing and/or for potash production. Attention must be given to the degree and type of control assumed in the derivation of these factors. Some unit conversions will also be necessary.

## g) Temporal Variability

No hourly, daily or seasonal temporal factors were identified for salt production.

## h) Geographical Variability

Production data is available on a provincial basis as well as a plant basis.

## i) Point Source Establishments

The following plants are listed on the Residual Discharge Inventory System maintained by Environment Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Nova Scotia | 120021 | Canada Rock Salt Ltd. | Pugwash |
| | 120022 | Domtar Chemicals, Salt Division | Amherst |
| Alberta | 480123 | Dow Chemical of Canada Ltd. | Fort Saskatchewan |

## References - Section A.06.2

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Statistics Canada, annual. "Non-Metal Mines". Catalogue No. 26-224.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory". EPA/600/7-87/015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.06.3 COAL TRANSPORTATION (SIC 06302)

### a) General Description

The coal industry involves three major steps: mining and handling, coal cleaning and beneficiation, and transportation. Coal mining and handling is inventoried under SIC 06301. Coal cleaning and beneficiation is inventoried under SIC 06300.

Coal transportation emissions include only those particulate matter emissions that occur from the coal during transit: load-in and load-out losses are included in the mining and handling sector and at the plant as part of fugitive emissions.

### b) Sector Description

Most of the coal mined in Canada is carried to trans-shipment or export terminals by unit trains. The coal imported into the country is shipped in lake vessels (Environment Canada 1983). Some minor amounts of coal are shipped by truck (Beak 1981).

Fugitive dust is the only emission inventoried from coal transportation. Emissions from fuel combustion (diesel, gasoline or oil) are inventoried separately as part of the transportation sector.

Before transport, the coal is often sprayed with chemical binders to reduce fugitive dust emissions. (SNC/GECO Canada Inc. and Ontario Research Foundation 1981)

Emissions from coal transportation are inventoried under SCC 53300.

### c) Inventory Approach

Coal transportation is inventoried as an area source using particulate matter emission factors based on the quantity and distance the coal is transported.

## d) Preferred Emission Estimation Procedure

Coal mined in Canada for internal use or export is assumed to be transported entirely by rail. Emissions from coal trains are dependent on such factors as speed, terrain, climate, use of chemical binders, type of coal and distance. Assuming the use of chemical binders and making typical assumptions for the Canadian situation, emission factors for rail transportation may be calculated using the distance of track and the relationship developed by Environment Canada as follows (SNC/GECO and ORF 1981):

$$\text{E.F.} = 0.1\ (\text{miles})^{0.6}\ \text{kg/tonne}$$

Emission factors specific to each province are based on the distance that coal is shipped via trains in that province. Routes of coal shipment must be determined and total mileage calculated. Table A.06.3-1 shows average shipment distances for each province (Environment Canada 1980). These are assumed to represent averages weighted on the basis of mass transported.

Emissions from imported coal, which is shipped, are estimated to be .1 kg/t (Beak 1981). Assuming that this loss is evenly distributed over the entire shipping period, emissions within Canadian territory are negligible.

## c) Activity Level

An annual report by Statistics Canada (Report No. 26-206) presents data on number of mines, production, disposition, exports and imports, and supply and demand by province.

Energy, Mines and Resources Canada also reports on coal and coke in its Canadian Minerals Yearbook.

### f) Alternative Emission Estimation Procedures

A report by Beak (1981) examines more detailed methods of estimating particulate matter emissions from coal transportation. Factors discussed include those for truck transport, moving trains (with and without chemical treatment), empty trains, stationary trains and ship transport. This level of detail, however, would require much more detailed activity level information and would only be recommended for local or industry-specific inventories.

### g) Temporal Variability

No temporal information was identified for coal transportation.

### h) Geographical Variability

Emissions are estimated on a provincial basis. Further spatial allocation could be based on the length of track in any given region. It should be noted that particulate matter emissions in cities are negligible because the trains slow down to a speed where dust emissions are not a problem. (Environment Canada 1980)

## TABLE A.06.3-1

### Prorated Distances Used to Calculate Provincial Emission Factors in the 1976 Environment Canada Inventory (Environment Canada 1980)

| Province | Prorated Distance (km) |
|---|---|
| B.C. | 1800 |
| Alta. | 1110 |
| Sask. | 1430 |
| Man. | 920 |
| Ont. | 960 |
| N.B. | 330 |
| N.S. | 220 |

## References - Section A.06.3

Beak Consultants Limited, 1981. "Coal-Fugitive Dust Emissions". Prepared for Atmospheric Environment Service, Downsview, Ontario.

Energy, Mines and Resources Canada, annual. "Canada Minerals Yearbook. Coal and Coke".

Environment Canada, 1980. Unpublished information.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, annual. "Coal Mines". Catalogue No. 26-206.

## A.06.4 ASBESTOS PRODUCTION (SIC 06210)

### a) General Description

The production of asbestos, in which naturally-occurring mineral silicates are recovered as fibres, involves two major operations: mining and milling. Chrysotile, a hydrous magnesium silicate, is the only variety of asbestos mined in Canada and most asbestos is produced in Quebec. Due to extensive regulatory developments regarding workplace hazards associated with asbestos, production has declined in the last decade, but most existing producers operated at full capacity during 1988 (EMR 1988). In producing asbestos, both ducted and fugitive particulate emissions, comprising rock dust and small asbestos fibres, occur in various operations, while emissions related to fuel combustion (in dryers) can be accounted for in the industrial fuel combustion sector. Reduction in particulate emissions from some operations might be expected in recent years with implementation of stricter control measures and industry process changes.

### b) Process Description

Asbestos Mining Operations (SCC 3-05-031-01 to 10):
Most of the asbestos-bearing ore is mined in open pits, while an underground mine is being developed in B.C. In the mining process, the fibre-bearing ore is extracted from the ground and transported to the mill. Potential emissions of particulate matter can occur from operations such as: overburden stripping, surface drilling and blasting, sorting, screening, loading, hauling and other stockpiling raw materials or waste handling and conveying operations. Although some of these operations are not readily amenable to dust control, individual bag collectors have been installed on drilling equipment (i.e., rather than wetting ores in cold temperature conditions) (EPS 1978).

Crushing (SCC 3-05-032-01):
Ore from the mine is crushed and screened in primary and secondary (i.e., jaw or gyratory) crushers prior to drying and waste rock is dumped. Dust filters on screens and grizzlies are commonly used.

Ore Drying (SCC 3-05-032-02):
Prior to milling, the crushed ore is dried in rotary and vertical tower dryers with heat provided by fossil fuels. Dryer emissions are normally controlled by a baghouse before exhausting to the atmosphere.

Milling (SCC 3-05-032-03 to 06):
The milling of asbestos ore involves the separation of the fibrous portion from rock achieved by successive stages of reduction in ore size. Crushers, impact breakers and fiberizers are used to release fibres, followed by screening and air aspiration in various stages to classify the products by grade for packaging. Ventilation hoods, in conjunction with cyclones and low-energy scrubbers, may be used for various milling and handling operations. On the other hand, these devices are not of high enough efficiency for final air cleaning and, thus, baghouse filter techniques are most commonly used for milling dust control (EPS 1977). Typical removal efficiencies of cyclones and baghouses are reported to be 70 and 99.8%, respectively (EPS 1983). In addition, a wet-milling process is being introduced in at least two Canadian facilities (EMR 1988) which should effectively reduce dust emissions from the milling process.

Tailing Piles (SCC 3-05-031-11):
Tailings, including very short fibres of little commercial value and waste rock, are generated from the various milling operations and dust collection equipment used on dryers, crushers, screens, product classifiers, etc. In addition to emissions resulting from handling and transporting these wastes to the tailings disposal area, potentially significant windblown fugitive dust emissions are estimated to occur from the tailing piles, especially under dry conditions. Efforts to control such emissions by wet agglomeration are reported to be practiced in some locations (Hutcheson 1971, Cook 1978, Taylor 1978). Similarly, one plant in Newfoundland is installing a wet

process to recover short fibres from tailings (EMR 1988), whereby reduced emissions from this source might be expected.

### c) Inventory Approach

Point source methods should be used to compile particulate emissions from asbestos producers since emissions are reported in previous Canadian inventories to exceed 100 tonnes per year at each plant and a limited number of facilities exist in Canada. Use of either recent source test data, where available for a given operation, or emission factors will be required with factors derived for some operations by engineering estimates.

### d) Preferred Emission Estimation Procedure

Information sources that can be used to estimate particulate emissions resulting from primary asbestos production include:

- emission factors developed by Environment Canada (EPS 1983) based on a report of the industry (EPS 1977),
- emission factors derived for Quebec operations in an Environment Canada report (Leroux 1983).

It is recommended to contact asbestos producers, in order to obtain any available recent source measurement data that might be used in preference to reported emission factors. For example, emission factors reported by Environment Canada are based upon estimates or, in some instances, measurements conducted prior to 1980. The total particulate emission factors reported for asbestos production in Quebec (Leroux 1983) are listed below:

| Process | Controlled Particulate Emission Factor (kg/tonne fibres produced) |
|---|---|
| Crushing | 0.13 |
| Drying | 0.96 |
| Rock Storage | 0.25 |
| Milling | 3.79 |
| Tailing Piles | 18.31 |

These differ from earlier values reported by Environment Canada (EPS 1983) that were expressed in units of kg/tonne of ore mined and have been adopted in subsequent inventories. In some instances, the emission factors for various mining and milling operations were based upon maximum permissible total particulate concentrations of 50 mg/m$^3$, manufacturer guarantees that asbestos emissions controlled by fabric filter baghouses do not exceed 2 fibres/cc and verification by sampling at several emission points that concentrations were below the permissible limits. The fugitive particulate emission factors for tailing pile losses were based on engineering estimates of a working group. These emission factors may possibly overestimate current emissions for various facilities due to recent process changes and implementation of more stringent control measures. Similarly, because of the complexities in measuring fibrous particles incorporated in dust, and the high dependency of control device efficiencies on emission rates, the extent to which these emission factors represent all facilities is uncertain. It is noteworthy that measured asbestos fibre concentrations in ducted exhaust controlled by baghouses at an asbestos fibre manufacturing plant ranged from 0.035 to 0.074 fibres per cc, depending on the plant location (EPS 1980). These concentrations are substantially lower than the concentrations used for deriving the above emission factors, but the dust loadings at the manufacturing plant might also be expected to be significantly lower than loadings in milling operations. Nevertheless, until additional measurement data are available to verify or improve on the above-reported emission factors, it is recommended that these be applied.

## e) Activity Level

Base quantity and/or operating information for individual asbestos producers should be obtained from provincial government agencies or direct industrial contact. It is recommended that the following type of information be requested for each facility:

- the annual amounts of ore processed and asbestos produced, as well as operating hours (seasonal, daily, hourly),
- the general characteristics of operations (e.g., open pit or underground mine, dry or wet processing, secondary wet-processing of tailings, etc.),
- the type and particulate removal efficiencies of control devices employed in each operation,
- the type and amounts of feed used in ore drying or other operations,
- the type of fugitive dust suppression methods, especially for tailing disposal areas,
- available measurement data and supporting documentation.

The emission rates for each facility can then be estimated in accordance with the amount of asbestos produced and test data or applicable emission factors for each major operation. Should control devices other than baghouses be used at any given milling facility, the value of the controlled emission factor noted above should be apportioned according to the removal efficiency of the in-place control device.

## f) Alternative Emission Estimation Procedures

In the event that base quantity data cannot be readily acquired, published normal mill capacities (in fibre/year) for each Canadian asbestos producer is provided in the Canadian Minerals Yearbook (EMR 1988). Actual asbestos production by province is also reported in the Canadian Mining Journal which can be prorated for each facility based on capacity data, in order to estimate emissions.

## g) Temporal Variability

It is recommended to acquire typical mill operating schedules by industry contact, so as to derive seasonal, daily and hourly emission temporal factors.

## h) Geographical Variability

Locations of each major asbestos production facility in Canada is known which will readily permit geographical apportioning of emissions.

## I) Point Source Establishments

On the basis of Environment Canada point source listings and EMR publications, the following primary asbestos producers are operating in Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Newfoundland | 100008 | Baie Verte Mines Inc. | Baie Verte |
| Quebec | ? | Lac d'amiante du Quebec | Black Lake |
|  | ? | Asbestos Corp. - British Canadian Mine | Black Lake |
|  | ? | Bell Asbestos Mines Ltd. | Thetford Mines |
|  | ? | JM Asbestos Inc. - Jeffrey Mine | Asbestos |
| British Columbia | 590048 | Cassiar Mining Corp. | Cassiar |

## References - Section A.06.4

Canadian Mining Journal, 1989. "Canadian Mineral Production", March.

Cook, D., 1978. "Milling, The Cassiar Story", CIM Bulletin: 88-95, April.

Energy, Mines and Resources (EMR), 1988. "Canadian Mineral Yearbook 1988".

Environment Canada (EPS), 1977. "Air Pollution Emissions and Control Technology, Asbestos Mining and Milling Industry". Report EPS-3-AP-76-6, February.

Environment Canada (EPS), 1978. "Standard Reference Method for Source Testing: Measurement of Asbestos from Asbestos Mining and Milling Operations: Method S-3, Sampling of Drill Baghouse Exhaust Emissions", Reports EPA-1-AP-75-1 and 1A, March.

Environment Canada (EPS), 1980. "Air Pollution Emissions and Control Technology: Asbestos Manufacturing Industry", Report EPS 3-AP-80-2, August.

Environment Canada (EPS), 1983. ""A Nationwide Inventory of Emissions of Air Contaminants (19878)". Report EPS 3-EP-83-10, December.

Hutcheson, J., 1971. "Environmental Control in the Asbestos Industry of Quebec", CIM Bulletin: 83-89, August.

Leroux, M., 1983. "Inventoire des emissions de polluants atmospheriques, Quebec (1980)", Environment Canada Report, March.

Taylor, M., 1978. "The Environment, The Cassiar Story", CIM Bulletin: 101-103, April.

## A.06.5 GOLD PRODUCTION/ROASTING (SIC 06110)

### a) General Description

Gold is recovered by cyanide leaching of gold ore, contained in tanks or arranged in heaps, by operations such as: amalgamation, flotation, gravity concentration, smelting or a combination of these. Further recovery from the leach solution may be achieved by precipitation zinc dust or adsorption on activated carbon (U.S. Bur. of Mines 1985, CMJ 1990). Several gold mining and milling operations exist in Canada that use conventional processing. However, certain Canadian ores and flotation concentrates contain arsenic which interferes with cyanidation or gold which is finely dispersed in sulphide minerals that reduces dissolution. On the basis of published information, roasting operations are used at only three Canadian gold producers, in order to provide a calcine that is amenable to cyanidation (EPA 1979). Emissions of arsenic trioxide and/or $SO_2$ can be expected to result from the roasting process. It is evident, from the principal processes noted in a publication by the Canadian Mining Journal, that one facility in Ontario (Dickenson Mines) no longer operates a roaster (CMJ 1990, Werniuk 1990).

### b) Process Description

<u>Gold Roasting</u> (SIC 3-03-013-XX):
Concentrate from the flotation circuit is directed through two fluidized bed roasters positioned in series which are heated above 300°C to remove arsenic and sulphur from the concentrate. The calcine roaster product is then leached with cyanide. At one facility in Ontario (Kerr Mines), a somewhat dated Environment Canada report indicates that roasting of tailings is done in a single stage, fluid-bed reactor only during winter months (EPS 1979). After passing through a cyclone and cooling, the off-gases which contain dust, $SO_2$ and sublimed arsenic trioxide are then passed through an electrostatic precipitator and warm fabric filter baghouse, in order to control emissions and ensure dust recovery.

## c) Inventory Approach

It is recommended to use point source methods to inventory emissions from these facilities. Either individual gold producers using roasters or provincial government environmental ministries should be contacted in order to acquire updated process and emissions information. Where necessary, either material balances or emission factors developed for this process by Environment Canada should be used to estimate emissions.

## d) Preferred Emission Estimation Procedure

Rather limited information has been found regarding emissions from gold roasting operations with the exception of an Environment Canada publication concerning arsenic emissions (EPA 1979). Thus, it is recommended to contact individual producers, in order to acquire any emission testing data and process information. Along with base quantity requirements noted below, examples of the types of information that should be requested includes:

- available emission test data for $SO_2$, particulate matter and/or other emissions along with supporting documentation to ensure that test data represent current operating conditions,
- emission control devices being used and corresponding removal efficiencies,
- roaster feed and product sulphur concentrations, as noted below, in order to verify emissions data by material balance.

## e) Activity Level

Specific production data for gold mining operations are available in the following publications:

- the amount (kg) of gold produced by province (EMR 1988, CMJ 1989),
- mill capacities (tonnes ore/day) and ore treated (tonnes) with gold content for individual producers (CMJ 1989),

- mill capacities (tonnes ore/day) and gold content of ore and concentrate grade for selected gold processing plants with notes on operations (CMJ 1990).

It is evident that published data are limited with which to derive appropriate base quantities for estimating gold roaster emissions. Thus, base quantity and operating information for Canadian gold producers that use roasters should be obtained by direct industrial contact or from provincial government agencies. It is recommended that the following type of information be requested for each facility:

- general process information related to emission sources (e.g., number and type of roasters along with feed types or fuels use) and operating hours (e.g., seasonal, daily, hourly),
- the annual amounts of ore processed (e.g., milled) and flotation concentrate or tailings roasted,
- the sulphur content of the following input materials: the ore processed, flotation concentrate and/or other feeds to roasters, and the calcine product,
- the types and removal efficiencies of emission control devices (e.g., dust controls, use of lime in heat exchangers, etc.).

Emission rates of $SO_2$ can then be estimated on the basis of either source test data and/or sulphur material balances, in conjunction with the best available base quantity data. Should a sulphur balance be used to determine emission rates or verify reported emission measurement data, a more accurate balance will be achieved using the amounts and sulphur content of roaster feeds (e.g., flotation concentrate), rather than ore processed.

### f) Alternative Emission Estimation Procedure

Where less accurate emission compilations are required, emissions can be estimated using reported emission factors for plants with roasters and published base quantity data. The following $SO_2$ emission factors have been derived in an unpublished Environment Canada report (ORF 1987):

| Source | $SO_2$ Emission Factor (kg/tonne of Ore Milled) |
|---|---|
| Campbell Red Lake - Balmertown | 36.3 |
| Kerr Addison - Virginiatown | 26.4 |

These emission factors were back-calculated on the basis of known production rates and emissions data provided to Environment Canada by the Ontario Ministry of the Environment. The amount of ore treated for a given facility would need to be prorated, based on the published amount of ore treated in 1988 (CMJ 1989) with the mill capacities by facility reported for 1988 and the given base year (e.g., CMJ 1990).

### g) Temporal Variability

Operating information for gold roasters, acquired through industrial contact or production notes published by EMR for given facilities (EMR 1988), should be used to derive seasonal, daily and hourly emission temporal factors.

### h) Geographical Variability

Locations of gold roasting facilities are known, whereby emissions can readily be geographically apportioned.

### i) Point Source Establishments

On the basis of information reported in the Canadian Mining Journal (CMJ 1990), the following gold-producing facilities are presumed to maintain the roaster operation. Stack parameters data are available in Environment Canada Inventory Management Division files.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351341 | Placer Dome Inc. (Campbell) | Balmertown[1] |
|  | 351331 | Golden Shield Resources (Kerr) | Virginiatown[2] |
| NWT | ? | Giant Yellowknife Mines | Yellowknife[3] |

1. Roasters are reported to currently operate (CMJ 1990, Scales 1990)
2. This facility continues to produce gold,but the roasting process known to operate previously was not stated explicitly (CMJ 1990, EMR 1988)
3. This facility continues to produce gold and it is presumed that roasters currently operate (CMJ 1989)

## References - Section A.06.5

Canadian Mining Journal (CMJ), 1989. "Canadian Mineral Production - 1988", Canadian Mining Journal:16-28, March.

Canadian Mining Journal (CMJ), 1990. "1990 Mining Sourcebook".

Energy, Mines and Resources (EMR), 1988. "Canadian Minerals Yearbook - 1988".

Environment Canada (EPS), 1979. "Arsenic Emissions and Control Technology: Gold Roasting Operations", Air Pollution Control Directorate Report EPS 3-AP-79-5, September.

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern North America", ORF Final Report P-5134/FG for Environment Canada, March.

Scales, M., 1990. "The Big Dome Celebrates 80 Years", Canadian Mining Journal:3-31, September.

U.S. Bureau of Mines, 1985. "Mineral Facts and Problems - 1985 Edition". U.S. Department of the Interior, Bureau of Mines Bulletin 675.

Werniuk, J., 1989. "Gold-rich Red Lake Camp Continues to Produce", Canadian Mining Journal: 13-21, September.

## A.06.6 POTASH PROCESSING (SIC 06240)

### a) General Description

Potash is a generic term that includes potassium chloride (most common form), potassium magnesium sulfate, potassium sulfate, potassium nitrate, and potassium-sodium nitrate mixture. Whatever the composition, potash is expressed as a $K_2O$ equivalent in order to provide a common denominator for production and sales data (U.S. Bureau of Mines 1985).

Sylvite, a mineral and the main source of potash, is mined either by underground excavation or by solution extraction. Broken rock or potash-rich solutions are transferred to the surface plant where refining and processing takes place (SNC/GECO Canada Inc. and ORF 1981).

Particulate matter is emitted from the above ground operations.

### b) Process Description

The main source of potash, sylvite (KCl), is usually found in association with halite (NACl) and is mined either by underground mining or by solution extraction. Broken rock or potash-rich solutions are transferred to the surface plant where further refining, by flotation and/or evaporation and crystallization takes place. (SNC/GECO Canada Inc. and ORF 1981).

Ore recovered by conventional mining methods is crushed and deslimed and the coarse potash recovered by flotation. Fine potash derived from the ore or dust from subsequent processing is dissolved in hot brine and potash is recovered by crystallization. The recovered potash is then dried in a rotary dryer, screened, and processed further to make fertilizers. Portions of the flotation concentrates which are not coarse enough to make the desired product are agglomerated by dry compaction. (SNC/GECO Canada Inc. and ORF 1981).

Evaporation and crystallization refining techniques are used in conjunction with solution mining of the potash ore body. Processing steps are similar to those for conventional ore processing. (SNC/GECO Canada Inc. and ORF 1981).

Product drying and screening operations are the major particulate emission sources. Other emission sources include: raw ore storage and reclaim, ore dry crushing, product storage and loadout. A unique particulate emission problem arises during the evaporation of brines using submerged gas combustion. The salts become dissociated in contact with the natural gas flame and do not recombine until conditions are cool enough, generally in the stack. The result is a rather opaque white plume of fine submicron particles of KCl and NaCl too fine to be collected by conventional scrubbers. (SNC/GECO Canada Inc. and ORF 1981).

Particulate emissions in the solution mining plants are restricted to operations subsequent to product drying. (SNC/GECO Canada Inc. and ORF 1981).

Particulate emissions are a difficult control problem in potash processing due to the nature of the material to be collected. KCl and NaCl are slightly hygroscopic and readily cake at the wet-dry interfaces of wet collectors or cake in dry collectors under conditions of high humidity. Wet collectors pose problems with plant solution balances since water used for scrubbing must be bled with loss of product, or evaporated, to keep solution quantities under control. If saturated brines are used as spray water, problems with crystallization and spray nozzle plugging frequently occur. In the product screening areas dry dust collection is preferred for solution balance reasons. Baghouses have been applied with mixed success. In humid regions operations have been unsuccessful. High humidity days lead to caking of the potash on the bags, effectively preventing filtration. The bags have to be removed and washed to restore activity. (SNC/GECO Canada Inc. and ORF 1981).

Potash production is inventoried under SCC 3-05-022-XX.

Emissions from a rotary dryer are usually controlled by dry cyclones followed by either a wet separator (wet impingement, cyclonic scrubber, wetted approach venturis) or by electrostatic precipitation. Precipitators, while not common, can give reasonably low emissions and fair reliability. Effectiveness can be reduced by shorting that occurs between the electrodes in humid conditions due to the presence of salts. (SNC/GECO Canada Inc. and ORF 1981).

## c) Inventory Method

Potash production facilities are inventoried as point sources of particulate matter. Site specific emission data is preferred. However, emission factors may be used in conjunction with site specific process and production data.

## d) Preferred Emission Estimation Procedure

Site specific emission estimates may be based on the following information:

- site specific process information, including information on process steps, process control used at each step, fugitive emission control procedures
- site specific emission information based on source testing, licensing information
- production data (in $K_2O$ equivalent) including scheduling if temporal data is required
- emission factors are available in a report by SNC/GECO Canada Inc. and ORF (1981) for controlled and uncontrolled major processes. These are based on unpublished information from the Saskatchewan Research Council. It is assumed that these emission factors are based on $K_2O$ equivalent weight. These emission factors may be used to confirm or supplement site specific emission information.

### e) Activity Level

Site specific production data is preferred. Alternatively, annual rated capacities of Canadian potash mines can be used to apportion total annual Canadian production figures to individual operations. Capacity information, by location, and annual production data (in $K_2O$ equivalent) are available in the Canadian Minerals Yearbook (Energy Mines and Resources 1989).

### f) Alternative Emission Estimation Procedure

If no site-specific data is available, total annual production data can be apportioned to individual operations as described in Section e). Typical controls can then be assumed to be in effect and particulate emissions predicted using the literature emission factors outlined in Section d).

### g) Temporal Variability

Monthly Canadian potash production data is reported in the Canadian Minerals Yearbook (Energy, Mines and Resources 1989). This can be used to derive monthly temporal factors.

### h) Geographical Variability

Potash production facilities are inventoried as point sources.

### i) Point Source Establishments

The following producers are listed in the Canadian Minerals Yearbook (Energy, Mines and Resources 1989). Details are also provided on facilities that are operated on a partnership basis, and which locations are mined using solution extraction.

| Province | Company |
|---|---|
| Saskatchewan | Potash Corp. of Sask:<br>- Allan<br>- Cory<br>- Esterhazy<br>- Lanigan<br>- Rocanville<br>Central Canada Potash<br>Cominco Ltd.<br>International Minerals & Chemical Corp.<br>Kallium Chemicals<br>Potash Company of America Inc.<br>Saskterra Fertilizers Ltd. |
| New Brunswick | Denison Mines Limited<br>Potash Company of America Inc. |

## References - Section A.06.6

Energy, Mines and Resources, 1989. "Canadian Minerals Yearbook".

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

U.S. Bureau of Mines, 1985. "Mineral Facts and Problems". Bulletin 675. U.S. Bureau of Mines.

## A.06.7 PYRRHOTITE ROASTING (SIC 06172)

### a) General Description

As part of one Canadian nickel refining complex, pyrrhotite concentrate is roasted to produce sulphuric acid. Significant $SO_2$ emissions have been associated with this process.

### b) Process Description

Pyrrhotite Roasting (SCC _______)

In the preparation for smelting nickel and copper at this plant, the metal fractions in the milled ore are concentrated in a series of magnetic separation and flotation circuits (Scales 1988). An excess amount of pyrrhotite from the ore is generated which is a low value iron sulphide concentrate containing approximately 35% sulphur and only small amounts of the metal values (MOE 1987). The pyrrhotite concentrate is currently piped to the Iron Ore Recovery Plant (IORP) where it is oxidized in fluidized bed roasters. The $SO_2$ contained in the off-gases is collected to produce sulphuric acid and the magnetite formed in the roasters is discarded to a separate tailings area for potentially future reprocessing (Scales 1988). A large fraction of the particulate matter in the roaster gases is removed by cyclones and electrostatic precipitators before entering the acid plant (Segworth 1974, EPS 1983) and some $SO_2$ is emitted at the acid plant. Several processing changes are being investigated and implemented at this smelter complex in order to both reduce $SO_2$ emissions from the entire plant and increase smelting productivity (MOE 1987, Scales 1988 and 1990). Amongst several options, if feasible, increased rejection of pyrrhotite in the circuits will reduce the extent of pyrrhotite roasting.

## c) Inventory Approach

Emissions from the facility should be determined as a point source using a mass balance approach, any reliable emission test data, where available, or a reported emission factor for this process.

## d) Preferred Emission Estimation Procedure

Unless source test data are available, $SO_2$ emissions from the roaster off-gases may be best derived from a sulphur mass balance based upon data procured from the producer. Examples of the types of information required include:

- the feed rate and sulphur content of the pyrrhotite feed to the roaster with account of other concentrate feeds (e.g., Ni concentrate that may be calcined at the IORP)
- the volumes and sulphur content of process air and any supplement fuel gases to the fluid bed roasted (if significant)
- the amounts and sulphur content of the magnetite product and any nickel calcine product from the roaster and/or other solid waste streams
- the volume and sulphur content of any roaster off-gases that are not directed to the acid plant (e.g., steam emissions if significant)
- the $SO_2$ conversion efficiency of the sulphuric acid plant to collect $SO_2$ from the roaster off-gases with account of the generation rate and grade of $H_2SO_4$ produced and any excess acid generated from other process off-gases

## e) Activity Level

Base quantity and operating information for this pyrrhotite roasting process should be obtained from the provincial government agency or direct industrial contact. Where possible, information should be procured such as: the annual amount of pyrrhotite roasted, available source test data, sulphur mass balance information for the facility, control device information with removal efficiencies and the frequency of operation during the year. The previously annual quantity of pyrrhotite processed (EMR 1986) has not been reported in recent years; however, the nominal daily feed rate to the roaster has been published (Scales 1988).

## f) Alternative Emission Estimation Procedures

In the event that base quantity data and other process information cannot be readily acquired, emissions for the facility can be estimated from available data. An emission factor of 54 kg $SO_2$ per tonne of pyrrhotite roasted has been estimated in an earlier report (ORF 1987) on the basis of previous feed rates and reported $SO_2$ emissions. This can be used, in conjunction with the reported daily feed rate and available or assumed operating schedule information, to approximate the $SO_2$ emissions. However, this emission factor may not accurately represent current facility conditions and will depend to a large extent on the $SO_2$ collection efficiency by the sulphuric acid plant (see also Section A.37.2 regarding typical acid plant removal efficiencies).

## g) Temporal Variability

It is recommended to acquire typical roaster operating schedules by industry contact in order to derive seasonal, daily and hourly emission temporal factors. The normal daily operating schedule for all mill concentrators at this complex has been reported (Scales 1988).

## h) Geographical Variability

The location of this facility is known such that emissions can be readily apportioned geographically.

## i) Point Source Establishment

The following pyrrhotite roaster facility is operating in Canada.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351328 | Inco Ltd. - IORP | Sudbury |

## References - Section A.06.7

Energy, Mines and Resources Canada (EMR), 1986. "Canadian Minerals Yearbook - 1986".

Environmental Protection Service (EPS), 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1983)". Prepared by Environmental Protection Programs Directorate, Environment Canada, Report EPS 3-EP-83-10.

Ontario Ministry of the Environment (MOE), 1987. "Summary and Analysis of the Third Progress Reports (July 31, 1987) by Ontario's Four Major Emitters of Sulphur Dioxide".

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Unpublished Report P-5134/FG prepared for Inventory Management Division, Environment Canada.

Scales M., 1988. "Striving for Efficiency - Inco Looks at Consolidation of Sudbury Mills", Canadian Mining Journal:43-48, June.

Scales, M., 1990. "Inco Digs into Deep Pockets", Canadian Mining Journal:15-19, September.

Segsworth, V.K., 1974. "Inco's $SO_2$ Emission Control Program". Paper presented at the 21st Ontario Industrial Waste Conference, Skyline Hotel, Toronto. June 21, 1974.

## A.07.1 CRUDE OIL PRODUCTION (SIC 07113)

### a) General Description

This sector involves the production, transportation and storage of domestic crude oil, and the unloading and storage of foreign crude oil. Only VOC fugitive emissions losses are inventoried for these sources.

### b) Sector Description (B.H. Levelton & Associates Ltd. 1988)

In all, there are three sources of fugitive VOC emissions from this sector.

The first source includes the well pumping operation and pipeline transportation of domestic crude oil.

The second source consists of the unloading operation of marine vessels used for the import of foreign crude oil.

The third source type involves the handling and storage of crude oil in tank farms within the crude oil transportation network, i.e. exclusive of crude oil storage at refineries.

These are inventoried under SCC 52110 (Oil and Gas Production - Crude Oil - Evaporation).

### c) Inventory Approach

Crude oil production is inventoried as an area source, using volume-based emission factors.

### d) Preferred Emission Estimation Procedures

The U.S. EPA have estimated emission factors for fugitive emissions generated by the production and transportation of crude oil (U.S. EPA 1976). For domestically produced crude oil these fugitive sources include compressor seals, relief valves, wastewater separators, pipeline valves and pumps. The emission factors used by Environment Canada for domestic and foreign crude oil production and transportation are:

| | | |
|---|---|---|
| Domestic crude | 305.0 | kg/$10^6$ L crude oil production |
| Foreign crude | 275.0 | kg/$10^6$ L crude oil unloaded |

Emission factors for handling and storage sources are in the 1985 NAPAP listing (SCC 4-04-003-XX) (U.S. EPA 1987). These factors are available for three tank designs and two seal designs for the external floating roof tank. (B.H. Levelton & Associates Ltd. 1988)

## e) Activity Level

Provincial crude oil production and imported volumes are available from Statistics Canada (Publications 26-213 and 54-209) and the Petroleum Association for Conservation of the Canadian Environment (PACE 1985). Imported crude oil generally enters Canada through eastern ports and is primarily refined in the Atlantic provinces. Further data on import crude statistics can also be obtained through Energy, Mines and Resources, Canada. (B.H. Levelton & Associates Ltd. 1988)

Where crude oil data is reported on a weight basis, a conversion factor of 1.17 $m^3$/tonne may be used. This conversion factor was developed from Statistics Canada publications 26-213 and 54-209 by Environment Canada for use in the 1985 NAPAP inventory. This factor is within the ranges of specific gravities reported for crude oil (0.80-0.97 tonnes/$m^3$).
The only reliable statistics available on crude oil storage capacity at oil fields and ship terminals are directly from the operators. Major oil producing companies, pipeline operators and port authorities should, therefore, be consulted to estimate the storage volume capacity at the well sites, transfer stations and receiving facilities. (B.H. Levelton & Associates Ltd.)

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Some limited information on seasonal daily and hourly temporal factors for domestic crude oil production is available (The MEP Company and Ontario Research Foundation 1985).

### h) Geographical Variability

Data for domestic production and foreign imports are available on a provincial basis.

## References - Section A.07.1

B.H. Levelton & Associates Ltd., 1988. "VOC Emissions Methods Manual". Report prepared for Environment Canada by B.H. Levelton & Associates.

The MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Petroleum Association for Conservation of the Canadian Environment, 1985. "Canadian Petroleum Refineries Atmospheric Emissions Survey - 1983". PACE Report 85.1. Ottawa.

Statistics Canada, "The Crude and Natural Gas Industry". Publication No. 26-213.

Statistics Canada, "International Seaborne Shipping Statistics". Publication No. 54-209.

U.S. Environmental Protection Agency, 1976. "Revision of Evaporative Emission Factors". EPA-450/3-76-039. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.07.2 TAR SANDS OPERATIONS (SIC 07121)

### a) General Description

Developed tar sands deposits in Canada are only found in Northern Alberta. Tar sands operations involve the extraction of bitumen from oil sands. For shallow deposits, surface mining techniques are used followed by conditioning, separation and upgrading (clearing) processes. For deeper deposits in-situ techniques such as in-situ combustion or steam stimulation must be used to reduce the viscosity of the oil to make it pumpable. The oil may then be put through separation and upgrading processes prior to refining at existing petroleum refineries.

Emissions to the atmosphere from these operations include particulate matter, $NO_x$, CO, $SO_x$ and VOCs.

### b) Sector Description

The operations described below outline typical key process features. However, it must be emphasized that any tar sands operation is unique and must be characterized on a case-by-case basis.

Surface Mining:
For surface mining, the basic steps in the extraction of bitumen from oil sands are the mining operations, feed conditioning, separation of the bitumen, waste disposal and cleaning (upgrading) the bitumen concentrate. The synthetic crude product is then sent to conventional oil refineries by pipeline for further treatment.

Mining operations are typical of any surface mining situation: muskeg is removed and stockpiled; draglines or front-end loaders and trucks are then used to remove the overburden.

Conditioning is achieved by tumbling the feed with water, heating with steam and adding a surfactant. The conditioned pulp (70% solids) is pumped to separation cells where the coarse mineral matter settles and is pumped to the tailings pond. The floating bitumen froth is then fed to a final extraction plant, where it is diluted with naphtha to reduce the viscosity and heated to 70°C with steam. Centrifuging is then used to remove a further tailings fraction from the mixture. The product is then heated to distill off the naphtha, which is recycled, and water and is upgraded using standard methods. Off-gases from upgrading pass through a sweetening system for the recovery of elemental sulphur, and for a production of a synthetic gas. (Environment Canada 1983, ORF 1982 and 1985).

The main emission source is the power plant boiler (typically fuelled by pulverized coke or heavy oil) with emissions of particulate matter, $NO_x$, $SO_x$, CO and VOCs. Particulate emissions from these boilers are controlled by electrostatic precipitators. (Environment Canada 1983)

$SO_x$ is also released from sour gas flaring, with some particulate matter (SNC/GECO Canada Ltd. and ORF 1981, Environment Canada 1983).

VOCs may be released from exposed oil sands (this is temperature-dependent), through evaporation in the plant (mainly naphtha), and from the tailings area (naphtha). (ORF 1985)

In-Situ Processes:

In-situ processes involve two main stages: removal of the oil from the ground and product upgrading.

There are two types of processing schemes which reduce the viscosity of the oil in the reservoir to a pumpable state: thermal and non-thermal processes. Thermal processes include steam stimulation and in-situ combustion. Steam stimulation processes involve process boilers, which may be fuelled by coal, by-product coke, natural gas or oil. (ORF 1985)

In-situ combustion processes rely on burning a portion of the formation bitumen to reduce the viscosity of the deposit. Various phosphorus or chlorinated compounds may be used to initiate or maintain combustion. The bitumen produced from in-situ combustion process is much different from the original bitumen, generally having a higher H/C ratio, lower density and a lower ashphaltene and sulphur content. (ORF et al 1985)

Either process results in three phases from the production well: oil, water and gas. The gas phase (including methane, ethylene, ethane, propylene and propane) is very lean and normally vented to the atmosphere or flared. (ORF et al 1985)

Further product operation or upgrading (see surface mining) may not be done on site.

In-situ processes vary widely in their potential for emissions. Principal emission sources are any boilers used (particulate matter, NO, $NO_x$, $SO_x$, CO and VOCs) and gas flares ($SO_x$, particulate matter).

Non-thermal processes are not generally considered appropriate to the Canadian situation.

No SCCs are available to characterize tar sands operations. Boiler SCCs may be used (See Sections B.49.1 and B.56.3).

### c) Inventory Approach

It is apparent from the previous description that each tar sands operation must be considered as unique. Therefore, any attempt to inventory particulate matter, $SO_x$, $NO_x$, CO and VOC emissions from these operations must be based on site-specific process, operating, emissions control, emissions testing and licensing information. Each operation is inventoried as a point source.

The boilers must be included in the inventory for these locations, as their fuel usage is not likely to be included in the fuel use totals for the fuel combustion sectors (see Sections B.49.1 and B.56.3).

### d) Preferred Emission Estimation Procedure

As stated above, tar sands should be inventoried using site-specific data as follows:

- process information on all removal, conditioning, separation, upgrading, storage and waste management sufficient to identify and characterize potential points of release to the atmosphere,
- operating information including production and scheduling information and fuel usage,
- emissions control methods for all steps of the process and rated efficiencies,
- any emissions testing available,
- licensing information specific to emissions estimation.

This information can be used to derive site-specific emissions factors and hence emission estimates.

### e) Activity Level

Production data and fuel usage information should be obtained through direct contact with the operators.

Synthetic crude production can also be obtained from a monthly Statistics Canada publication (Report No. 26-006). Other potential data sources include the Alberta Ministry of Environment, the Energy Resources Board in Alberta, and Energy Mines and Resources Canada. (Edwards and Cotton 1988).

### f) Alternative Emissions Estimation Procedures

If site-specific emission factors are not available, the following sources provide some information on emission factors:

- a report on $NO_x$ emissions for Alberta (Alberta Environment 1987),
- a report on fine and total particulate emissions in Canada (SNC/GECO Canada Ltd. and ORF 1981),
- a primary sulphate inventory (ORF 1982),
- some limited VOCs are available in a report by ORF et al (1985).

Emission factors for industrial or electricity generation external combustion boilers (see Sections B.49.1 and B.56.3) may be used for estimating boiler emissions.

### g) Temporal Variability

No temporal data was found for tar sands operations.

### h) Geographical Variability

All tar sands developments are found in Alberta, and are inventoried as point sources.

### i) Point Source Establishments

The following point sources are listed in the Residual Discharge Information System maintained by Environment Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Alberta | 480016 | Suncor Inc., Tar Sands Group | Ft. McMurray |
| | 480144 | Syncrude Canada Ltd. | Ft. McMurray |

Production only sites include Wolf Lake and Cold Lake (in-situ production).

## References - Section A.07.2

Alberta Environment, 1987. "Nitrogen Oxides Emissions for Alberta, 1981-1985". Air Quality Control Branch, Pollution Control Division, Environmental Protection Services.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd. for Environment Canada.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Ontario Research Foundation, 1982. "Anthropogenic Sources and Emissions of Primary Sulphates in Canada". Prepared for Environment Canada.

Ontario Research Foundation, Occultex Consultants and FDC Consultants, Inc., 1985. "A Study on Health Implications in the Tar Sands and Heavy Oil Industries". Report No. P-4769/G (2nd. Rev.). Prepared for Supply and Services Canada.

Statistics Canada, monthly. "Crude Petroleum and Natural Gas Production". Report No. 26-006.

## A.07.3 NATURAL GAS PROCESSING OPERATIONS (SIC 07110)

### a) General Description

Natural gas processing involves the removal of hydrogen sulphide and heavy hydrocarbons from sour gas. The hydrogen sulphide stripped from the natural gas may subsequently be recovered in sulphur plants to produce elemental sulphur or incinerated to sulphur dioxide.

Gas processing plants on a national collective basis represent a significant source of $SO_2$.

Emissions of particulate matter, $NO_x$, CO and THC from fuel combustion associated with natural gas processing (i.e., boilers) and distribution systems (compressors) are also inventoried under SIC 07110. Use of natural gas as a fuel by these combustors is not included in the general industrial natural gas fuel use totals (see Section B.56.3, Industrial Fuel Combustion). As for other sectors, use of other fuels inventoried as point sources under SIC 07110 must be subtracted from industrial fuel combustion area source totals.

### b) Process Description

Natural gas is considered to be "sour" if hydrogen sulphide is present in amounts greater than 4 ppm. Natural gas "sweetening" involves the removal of hydrogen sulphide and heavy hydrocarbons from the sour gas. Hydrogen sulphide is stripped from the natural gas with an amine solution, and subsequently liberated with regeneration of the original amine solution. (Environment Canada 1983, SNC and ORF 1981)

The recovered hydrogen sulphide gas stream may be vented, flared in waste gas flares or smokeless flares, incinerated or utilized for the production of elemental sulphur or other commercial products. (U.S. EPA 1985)

The following SCCs may be used to describe $SO_2$ emitting sources at natural gas processing plants:

<u>3-10-002-01</u> This is used to describe the amine process. If smokeless flares or tail gas incinerators are used (i.e., hydrogen sulphide is forwarded to sulphur recovery or sulphuric acid plants), there is virtually 100 percent conversion of $H_2S$ to $SO_2$. Only minor particulate and hydrocarbon emissions result from these devices and, because gas temperatures are not high, nitrogen oxides are not formed (U.S. EPA 1985). If hydrogen sulphide is recovered, emissions from the sweetening plant itself are very low and are accounted for as part of the recovery process.

<u>3-10-002-02</u> This SCC is used to describe gas stripping operations, in which the sweetened gas is divided into natural gas ($C_1$ + $C_2$), liquified petroleum gas ($C_3$ + $C_4$) and higher hydrocarbons ($C_5$ + $C_6$) components. Potential sources of emissions (mainly $SO_x$) include emergency flares or vents.

Other sources which could be inventoried at natural gas processing operations include (with the relevant SCC):

| | |
|---|---|
| 3-10-002-03 | Compressors |
| 3-10-002-04 | Wells |
| 3-10-002-05 | Flares (Miscellaneous) |
| 3-10-002-06 | Gas Lift |
| 3-10-002-07 | Valves (Fugitive Emissions) |
| 3-10-002-99 | Others Not Classified |

Emissions of suspended particulate matter, $SO_x$, $NO_x$, CO and VOCs due to industrial fuel combustion, are inventoried under the SCC system described in Section B.56.3, although process heaters and boilers may be inventoried under SCCs specifically related to oil and gas production fuel-fired equipment:

| | | | |
|---|---|---|---|
| 3-10-004-01 | Process Heaters | - | Distillate Oil |
| 3-10-004-02 | Process Heaters | - | Residual Oil |
| 3-10-004-03 | Process Heaters | - | Crude Oil |

| | | | |
|---|---|---|---|
| 3-10-004-04 | Process Heaters | - | Natural Gas |
| 3-10-004-05 | Process Heaters | - | Process Gas |
| 3-10-004-11 | Steam Generators | - | Distillate Oil |
| 3-10-004-12 | Steam Generators | - | Residual Oil |
| 3-10-004-13 | Steam Generators | - | Crude oil |
| 3-10-004-14 | Steam Generators | - | Natural Gas |
| 3-10-004-15 | Steam Generators | - | Process Gas |

VOC emissions may also originate from product and fuel storage.

Natural gas processing may also be coded using area source SCCs:

| | | | | |
|---|---|---|---|---|
| Process: | 52210 | Natural Gas Processing | - | Natural Gas Processing |
| Fuel Combustion: | 52220 | Natural Gas Processing | - | Heaters, Boilers In-Plant |
| | 52230 | Natural Gas Processing | - | Compressor Turbine In-Plant |
| | 52240 | Natural Gas Processing | - | Compressor Engine Non-Plant |
| | 52245 | Natural Gas Processing | - | Compressors In-Plant |

## c) Inventory Approach

Natural gas processing operations are inventoried as point sources of particulate matter, $SO_x$, $NO_x$, CO and VOC from the processing operations and natural gas or process gas combustion in related process heaters and boilers using plant-specific emission information. Other fuel combustion (i.e., residual oil, distillate oil and crude oil) may also be inventoried as point sources for these operations, as described in a) above and Section B.56.3. Natural gas combustion in off-site compressors is inventoried as an area source using emission factors from the literature.

## d) Preferred Emission Estimation Procedure

The preferred method of inventory for natural gas processing is to inventory each plant as a point source, using site-specific operating and emissions data supplemented as necessary by emission factors from the literature and provincial or federal production/fuel usage statistics.

Information sources used to calculate particulate matter, $SO_x$, $NO_x$, CO and VOC emissions for natural gas processing operations include:

- emissions and emission factors developed by Alberta Environment (Environmental Protection Services)
- AP-42 emission factors (U.S. EPA 1985)
- NAPAP inventory emission factors (U.S. EPA 1987).

Direct contact with individual producers is recommended to obtain available emissions and operating data. A sulphur material balance may also be used to estimate or cross-check $SO_2$ emissions from the flares or incinerators, based on the assumption that all of the sulphur stripped from the natural gas is converted from $H_2S$ to $SO_2$. The plant-specific information to be requested includes:

- available measurement data
- process-specific production data in terms of natural gas processed and sulphur contents of sour and sweetened gas
- operating schedules
- the usage, type and removal efficiencies for any pollution control devices
- amounts and types of fuel consumed for process and heating purposes

The use of sulphur recovery plants at natural gas processing plants in Canada is presently uncertain.

While site-specific emissions data are preferable, it is likely that emission factors will be required in many cases, particularly for fuel combustion-related emissions. As stated previously, natural gas combustion must be inventoried for this sector: other fuels may be included in area source calculations for industrial fuel combustion.

There is one exception to the point source methodology; compressors used for pipeline distribution systems would be inventoried as area sources under SCC 52240, using emission factors from the literature.

## e) Activity Level

Natural gas processing and fuel combustion data can be obtained from a number of sources:

- direct contact with companies
- Energy, Mines and Resources
- Energy Resource Conservation Board
- provincial and federal environment ministries
- Statistics Canada (particularly publications 26-006 and 57-003)

Where feasible, direct contact with individual companies is recommended to obtain operating data (volumes of gas processed, sulphur content information, etc.). Where fuel consumption information is obtained through plant contact, amounts of fuel (other than natural gas) should be deducted from those compiled for general industrial fuel combustion (see Section B.56.3).

## f) Alternative Emission Estimation Procedure

Natural gas processing plants could be inventoried entirely as area sources of particulate matter, $SO_x$, $NO_x$, CO and VOCs, using provincial or federal production statistics and emission factors from the literature (see section d)). In this case, only natural gas use will likely be available as a separate statistic for the natural gas processing industry. Residual oil, distillate oil and crude oil combustion would be included as part of the industrial fuel combustion sector.

## g) Temporal Variability

Plant-specific operating data can be used to determine seasonal, daily and hourly temporal factors. Also, the Statistics Canada publication 26-006 is issued on a monthly basis and 57-003 is issued on a quarterly basis.

### h) Geographical Variability

Natural gas processing facilities are inventoried as point sources. Most are located in Alberta, with the remainder in Saskatchewan and British Columbia.

### i) Point Source Establishments

Currently, there are over 200 point source establishments included in the Environment Canada Residual Discharge Inventory System. A list of these can be obtained from the Conservation and Protection Branch.

## References - Section A.07.3

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10.

SNC/GEC Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada (monthly). "Crude Petroleum and Natural Gas Production". Publication No. 26-006.

Statistics Canada (quarterly). "Quarterly Report on Energy Supply-Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutants Emission Factors. Volume I: Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A, B and C). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

# A.09.1 MINING AND PROCESSING OF MINERALS AND AGGREGATES

## a) General Description

The methods described in this section are generally common to a large number of different product industries and sectors in which mining, crushing and raw material preparation are accomplished in a similar manner. The inventory methods are common to specific processes for the following individual sectors:

| | |
|---|---|
| Mining and Rock Quarrying | (SIC 09290) |
| Stone Processing | |
| - Crushed Stone | (SIC 08110) |
| - Pulverized Stone | (SIC 08111) |
| - Building Stone | (SIC 35990) |
| Sand and Gravel Processing | (SIC 08210) |
| Silica Processing | (SIC 08211) |

The first sector encompasses mining and quarrying aspects (but not necessarily further processing) of the following minerals and aggregates: nonferrous and precious metals, iron ore, asbestos, potash, salt, coal, limestone, nepheline syenite and other ores or aggregates. Inventory methods addressing specific processing operations for some of these minerals are discussed in other sections of the manual. In most instances, particulate matter (of predominantly coarse size) is the primary pollutant associated with the above sectors and particulate emissions for some related operations can be significant. Particular care will be required in preparing inventories of such sources with regard to sorting individual process assignments between industries and activity locations, as well as defining point and area source distinctions, in order to include all contributions but avoid double-counting emissions.

Open Pit Mining and Quarrying (SCC 53410):
Metal and non-metal mining industries handle large volumes of a variety of materials, mostly rock, using several different mining techniques to extract the mineral from earth. In rock quarrying and open pit mining, some or all of the following operations are done prior to further

processing: overburden removal, drilling in rock or ore bodies, blasting, loading of materials, transporting raw materials by conveyors or haulage trucks, scraping, bulldozing, grading, etc. These operations represent uncontrolled open sources of generally coarse-sized fugitive dust, some of which are relatively minor sources. When necessary, dust suppression methods (e.g., watering) may be used. The major fugitive dust sources, also associated with the mining operations, are often reported (U.S. Bur. of Mines 1985, U.S. EPA 1986 and 1987) to be: blasting (where done frequently), hauling of materials by truck, bulldozing, open storage pile losses and wind erosion from exposed areas. The extent of emissions, which can be highly variable, depend on general sets of parameters such as:

- the extent of source activity
- properties of material disturbed
- implementation of dust control measures
- climatic conditions

Depending on the industry, further processing (e.g., sizing or separation of the mineral value from rock) may be done at the mine site or a separate processing plant. Most of the following resource materials are obtained from open pit mines and quarries: limestone, stone, sand, silica, gypsum, iron ore, asbestos, nepheline syenite and some coal. Examples of applicable inventory codes in the Environment Canada RDIS system that are used in relation to these operations include:

| SCC | Description |
|---|---|
| 53410 | Open Pit Mining and Quarrying |
| 53200 | Coal Mining - General |
| 53220 | Coal Mining - Overburden Removal |
| 3-05-010-21 | Iron Ore Mining - Overburden Removal |
| 3-05-031-02 | Asbestos Mining - Surface Drilling |
| 3-05-010-XX | Coal Mining - Several Operations |
| 3-05-010-15 | Coal Mining - Material Loading |
| 3-05-010-38 | Coal Mining - Truck Loading |
| 3-05-021-01 | Salt Mining - General |
| 3-05-020-XX | Limestone Quarries - Various Operations |

Underground Mining (SCC 53430):

Both non-metal and hard rock metal mining may be done underground to extract the mineral from seams. In addition to further processing, mining operations typically involve drilling or boring, blasting, crushing, loading and conveying ores through shafts and to the surface. In underground mines, the amount of particulate matter released to the atmosphere is naturally lower than from open pit mines, but can nevertheless be emitted through the ventilation systems. Again, fugitive emissions can occur from material haulage and open storage piles. Nonferrous metals, salt, potash and some coal are typically extracted from underground mines in Canada. Applicable inventory source codes include:

| SCC | Description |
|---|---|
| 53430 | Underground Mining |
| 53200 | Coal Mining - General |
| 3-05-021-01 | Salt Mining - General |
| 3-03-024-99 | Metal Mining - Not Classified |

Crushing and Screening (SCC 30-3-02X-XX, 3-05-01X-XX and 3-05-02X-XX):

Crushing operations are common to all mining and mineral processing facilities, in order to either size materials or separate valuable minerals from the gangue or rock matrix. Crushing operations for stone and other aggregate production are discussed below. In the mineral processing industries, ore from the mines or quarries is reduced in size in various stages, to achieve mineral separation with the amount of crushing, depending on the nature of the ore and processing requirements. Individual primary, secondary and sometimes tertiary crushing operations will often include equipment components such as: hopper, screen, crusher, surge bin, apron feeder and conveyor belt transfer points. Where controls are implemented, emissions from these various components are usually ducted to a single control device (e.g., wet scrubber or baghouse) (U.S. EPA 1985). Where necessary, final size reduction is usually accomplished by grinding in rod or ball mills. The ore is often ground in a water slurry to result in negligible particulate emissions while, in some dry grind, magnetic separation or air classification/conveying processes (e.g., some iron ore beneficiation facilities), particulate emissions can be significant. Dry cyclones are normally used for grinding operations involving air conveying and air classification. Dust can also be generated during material transfer operations (e.g., conveyor belt transfer points). Further ore beneficiation and recovery by physical or chemical separation is usually done in aqueous solution, whereby essentially no particulate emissions can be expected. Examples of inventory codes for these operations are:

| SCC | Description |
|---|---|
| 3-03-024-XX | Metal Ore - Various Crushing, Grinding Operations |
| 3-03-023-XX | Iron Ore - Various Crushing/Grinding Operations |
| 3-05-010-10 | Coal Mining - Material Handling/Crushing |
| 3-05-010-12 | Coal Mining - Material Handling/Screening |
| 3-05-022-01 | Potash Mining - Grind/Dry |

Drying (SCC 53440):
Concentrated mineral products, such as lead concentrate after flotation, may be dried to remove surface moisture. Although various types of units may be employed, natural gas-fired rotary dryers are most frequently used (U.S. EPA 1985). In iron ore beneficiation processes, iron ore pellets, with bentonite binders, are hardened to fusion temperature in the induration process using various types of natural gas or oil-fired drying furnaces (e.g., vertical shaft furnace, grate/kiln, etc.). Both particulate emissions and gaseous combustion products are released. Coal drying has been discussed in Section A.06.1 of this manual. The following source codes are applied to these operations:

| SCC | Description |
|---|---|
| 53440 | Mining and Rock Quarrying - Concentrate Dryers |
| 3-03-024-11 | Metal Mining - Ore Drying |
| 3-03-023-XX | Iron Ore - Indurating Furnaces |

Stone Processing - Crushed Stone (SCC 3-05-020-XX and 53611 to 15):
Stone processing involves the primary and secondary crushing, screening, milling and handling of stone aggregates following the removal from quarries. Although stone can be produced in a large variety of sizes (e.g., from building to pulverized stone), crushed stone accounts for the major amount of stone production in Canada. It is used

mainly as an aggregate in concrete and asphalt for constructing highways, buildings and railway beds (EMR 1989). Major rock types processed include limestone and granite with smaller amounts of sandstone, shale and other types. Many producers are part-time or seasonal, while large operations may be associated with construction or manufacturing establishments.

Quarried stone is normally trucked to the processing plant for primary crushing (e.g.., jaw, gyratory or impact crushers) and conveyed to secondary or tertiary crushers (e.g., cone, gyratory, hammermills or roll crushers). Various screening operations are associated with crushers as size reduction occurs (e.g. inclined vibratory screens are common). Processed crushed stone is usually stored in open area stock piles. Significant dust emissions may occur from these processing operations depending on factors such as: the rock type, feed size and reduction ratio, throughput rate, crusher type and surface moisture content of the rock (US EPA 1988). Although highly variable and only limited test data exist, greater dust emissions might be expected in successive stages of crushing as surface moisture evaporates. A large portion of the dust from such operations is coarse size and will settle within the plant by gravity. Fugitive dust sources include re-entrainment of settled dust by wind or machine movement. The extent of particulate emission control presumably depends on the proximity of operations to populated areas. Greater use of crushing emission controls (e.g.., cyclones, fabric filters, wet spray systems) and open dust suppression (e.g.., wetting techniques) might be anticipated for operations located in suburban areas. Source classification codes related to crushed stone processing operations are:

| SCC | Description |
|---|---|
| 53611 or 3-05-020-01 | Primary Crushing |
| 53612 or 3-05-020-02 | Secondary Crushing/Screening |
| 53613 or 3-05-020-03 | Tertiary Crushing/Screening |
| 53614 or 3-05-020-06 | Screening/Conveying/Handling |
| 53615 or 3-05-020-04 | Recrushing/Screening |

Stone Processing - Pulverized Stone (SCC 53621 to 53628): Pulverized stone (e.g.., limestone used for agricultural applications) undergoes processing similar to crushed stone but with additional crushing and screening operations to obtain finer sized material. Depending on the rock type and desired product, tertiary crushing, grinding or milling may be done with hammermills, rod mills or ball mills. The product is normally classified by dry vibrating screen systems or air classifiers and is conveyed/trucked to finished product bins. Both mechanical and fabric filter dust control systems might be expected to be used. Specific codes for pulverized stone processing are:

| SCC | Description |
|---|---|
| 53621 | Primary Crushing |
| 53622 | Secondary Crushing |
| 53623 | Recrushing/Screening |
| 53624 or 3-05-020-05 | Fines Mills |
| 53625 | Screening/Conveying |
| 53626 | Storage, Pile Losses |

Stone Processing - Building Stone (SCC 53631 and 3-05-020-08): Dimension stone is primarily granite or marble used for exterior and interior building surface cladding, tiles, monuments, furniture, etc. Approximately 90% of Canadian dimension granite production occurs in Quebec and a large fraction of building stone marble production occurs in Quebec and Ontario (EMR 1989). Rough dimension stone is usually cut from the rock face at the quarry site using drills and various combinations of diamond saws, wire saws and piercing equipment. Final cutting and finishing may be done at the quarry or transported to processing plants (U.S. Bureau of Mines 1985). Dust is generated mainly by the stone cutting operations.

Sand and Gravel Processing (SCC 53500 and 3-05-025-02 to 11): Sand and gravel deposits are quarried, transported to the plant and then classified and stockpiled. Many sand and gravel plants operate intermittently to supply local Canadian markets (EMR 1989). Several products compete with crushed stone as an aggregate for concrete and road base material but sand is also used in the glassmaking, foundry and abrasives industries (see below). As for other mineral aggregates, processing is accomplished by crushing, screening, washing, blending and stockpiling materials according to product specifications. Most process dust is reported to result from crushing operations which would normally settle at or close to the facility (Vandergrift 1971). However, at many plants, a substantial portion of the initially screened feed bypasses any crushing operations and is conveyed directly to wet processing operations where negligible air emissions are expected (SNC/ORF 1981, U.S. EPA 1988). Similarly, because many of the materials are moist when handled, particulate emissions are expected to be significantly lower than for similar crushed stone operations (Sittig 1975). Thus, only limited emission control equipment is expected to be used such as application of wet sprays (Environment Canada 1978, U.S. EPA 1988). The most important sources of dust at gravel pits and processing plants are wind-blown active/inactive storage pile losses and vehicular traffic on unpaved roads. These are usually seasonal fugitive emissions dependent upon local climatic conditions and can be controlled by dust suppression methods, windbreaks as well as product covers and enclosures. Pertinent codes for inventory preparation are:

| SCC | Description |
|---|---|
| 53500 or 3-05-025-01 | Total Plant General |
| 3-05-025-03 | Material Transfer and Conveying |
| 3-05-025-04 | Material Hauling |
| 3-05-025-10 | Crushing |
| 3-05-025-07 | Storage Piles |
| 3-05-025-99 | Not Classified |

Silica Processing (SCC 3-05-020-XX):

Silica sand (ie., 90-99% quartz) is quarried mainly for use by the glass industry. It is also used in metallurgical flux, casting sand in foundries, abrasives, fibreglass production and sandblast industries. Most is produced in Quebec and Ontario but facilities exist in each province (EMR 1989). Industrial sand processing operations are similar to those of construction sand production involving crushing/screening and may include wet milling, flotation, drying, air classifying and cracking of sand grains to form very fine products. Dust emissions originate mainly from the crushing and screening operations especially when grinding to very fine particle sizes (e.g., silica flour). Dry or wet screening and air classification may be practiced to achieve the desired size distribution. Drying and packaging of fine products are also of concern due to worker exposure to silica dust (U.S. Bureau of Mines 1985). Both wet and dry methods of dust control are used and baghouses are most commonly used. The following inventory codes for silica processing are the same as those for crushed stone operations:

| SCC | Description |
|---|---|
| 3-05-020-01 | Primary Crushing |
| 3-05-020-02 | Secondary Crushing |
| 3-05-020-04 | Recrushing/Screening |
| 3-05-020-05 | Fine Mills |
| 3-05-020-06 | Screening/conveying |
| 3-05-020-07 | Open Storage |
| 3-05-020-12 | Drying |

### c) Inventory Approach

Although individual mining, quarrying and processing establishments as well as specific processes might be expected to be significant sources of particulate emissions, prior Canadian inventories have traditionally treated emissions from many of these sectors as area sources. For practical reasons, the numerous mines and other associated operations, in conjunction with the highly variable nature of such emissions (e.g.., fugitive storage pile losses, dust from unpaved industrial roads, etc.) and lack of source testing, do not facilitate point source emissions to be calculated on a national basis. Thus, emission factors and other estimating procedures have generally been applied to determine provincial-level emissions. On the other hand, point source methods, incorporating region-specific information and source test data, where available, should be used to derive emissions on a local basis.

## d) Preferred Emission Estimation Procedure

Information sources that can be used to estimate particulate emissions resulting from mining and processing of minerals and aggregates include:

- emission factors developed by Environment Canada (EPS 1983),
- emission factors and general control device information reported in AP-42 (U.S. EPA 1985, 1988),
- uncontrolled emission factors reported for the NAPAP inventory (U.S. EPA 1987).

In several instances, the reported emission factors are based on limited source test data. Of necessity, the same factors are applied to similar types of operations that process quite different materials (e.g. primary and secondary crushing, etc.). Although it is not always known, the factors indicate that the amount of moisture in the material processed will substantially affect emission rates. In applying these factors, it will be necessary to assume the particular types of control devices used in the various operations and their removal efficiencies in order to estimate emissions for the various industries. It is also recognized that fugitive dust sources may, at times, dominate other process emissions. Single-value fugitive dust emission factors can be used to approximate emissions when no other information exists. However, because of the variety of process and local climate conditions, it is unlikely that the reported emission factors will accurately represent emissions for a given facility. Nevertheless, greater accuracy can be expected when such factors are applied to all facilities within a given sector.

When more reliable or localized emissions data are required, several types of information acquired from the facility can be used to improve the facility-specific emission estimates. In addition to individual process throughputs, the following data will assist in selecting appropriate emission factors:

- the types of mining and earth moving equipment employed at the facility,
- the moisture content of ores/rock processed throughout various stages,
- the extent of crushing done at different stages (e.g., particle size distribution or fraction of fines processed),
- the use of air classifying or conveying equipment,
- the methods of loading, conveying and unloading raw or processed materials as well as the number of conveyor transfer points,
- a clear distinction between integrated and non-integrated operations (e.g., the association of release points controlled by a common device),
- the types and removal efficiencies of control devices used including the degree to which inlet mass loadings are continuous or intermittent.

In order to better estimate fugitive dust emissions from haul roads and storage piles, empirically derived emission factor equations should be used provided that reliable correction parameter values can be obtained and that the values are within ranges used to develop the equations. As reported in AP-42 (U.S. EPA 1988), the following information should be acquired or determined to calculate dust from unpaved industrial roads (per vehicle kilometer travelled):

- a dimensionless particle size multiplier (where desired),
- the silt content of the road surface material (%),
- mean vehicle speed (Km/h),
- mean number of wheels for the particular vehicles,
- the number of days with at least 0.254 mm of precipitation per year.

For estimating windblown particulate emissions from open aggregate storage piles, expressed in g/m$^2$ per year (U.S. EPA 1988), the following information should be acquired:

- the type of material stored,
- the size and shape of the storage pile,
- the total exposed surface area ($m^2$),
- the roughness height (m),
- the frequency and extent of pile disturbances (ie., fresh exposure surfaces),
- the threshold friction velocity of the material (m/s),
- the wind direction and speed oriented to the pile for the fastest wind speed event to calculate the erosion potential.

### e) Activity Level

A variety of information is available in which to obtain or derive base quantities by province and, in some cases, individual producers. The following sources of published information are available:

Metal and Industrial Mineral - Mines and Processing Plants

- Operators List 1 (EMR 1977) provides individual mine or processing plant daily production capacity for major products including: non-ferrous metals, iron ore, asbestos, potash, gypsum, salt, nepheline syenite and others. The publication indicates the type of mine (underground or open pit) and specific notes on processes,
- Operators List 4 (EMR 1979) indicates individual coal mine annual outputs with notes on coal types, type of mine (underground or surface) and processing methods/equipment,
- Canadian Mining Journal (March 1989 Issue) summarizes statistics on principal individual mon-ferrous and precious metal mines and mills including: the type of metal, mine or mill daily capacity and annual quantities of ore milled,
- Canadian Minerals Yearbook (EMR 1989) provides statistics including: provincial shipments and individual company annual production of iron ore by mineral grade, provincial production of coal by type, individual asbestos producer daily capacities, Canadian potash production with individual company annual production capacities, provincial and Canadian annual salt

production by type with individual plant annual production rates, Canadian annual nepheline syenite production and other minerals/aggregates.

Stone Processing

- Canadian Minerals Yearbook (EMR 1989) summarizes annual provincial production statistics of quarried stone (all types), provincial production by type of stone (limestone, marble, granite, sandstone and shale), Canadian production by stone type and use (dimension, chemical/metallurgical, pulverized and crushed) and specific notes on major individual quarry operators.

Sand and Gravel Processing

- Canadian Minerals Yearbook (EMR 1989) summarizes annual provincial production rates of sand and gravel.

Silica Processing

- Operators List 1 (EMR 1977) provides daily capacities of silica produced by individual companies with specific notes on processing
- Canadian Minerals Yearbook (EMR 1989) summarizes annual provincial production of silica with notes on product types by major individual silica producers.

It is evident from the published base quantity information available for some of the mining and mineral processing industries that emissions are most suitably estimated at the provincial level (e.g. stone processing, sand and gravel processing). However, in some instances, production data are available to permit calculating emissions at the plant level (e.g. metal mines and ore processing operations). In either approach, reduced emission uncertainties can be expected if additional plant processing information is obtained. For example, the published annual production data either at the provincial or plant level, do not consistently relate to the throughput data associated with the reported emission factors. The emission factors have been determined from feed materials entering each stage of the particular operation (e.g., weight of material entering crushers or grinders and weights of materials handled at each transfer point). Without acquiring additional process information, estimates pertaining to the fractions of materials handled by such operations should be applied.

Similarly, the accuracy of fugitive dust emission estimates for open sources at mines and mineral processing facilities will partially depend on the extent of facility-specific and other climatological information acquired. Where data are lacking, substitute factors are reported to approximate fugitive dust emissions from sources such as material storage areas and haul roads. Alternatively, more reliable estimates can be derived for a given facility by acquiring activity-related and site-specific information applicable to the fugitive dust equations reported in AP-42 (U.S. EPA 1988).

### f) Alternative Emission Estimation Procedures

There is a general lack of measured emissions data for many operations in the mineral and aggregate processing industries presumably due to the variable nature of both process and fugitive dust emissions. Accordingly, there are essentially no practical alternatives to the use of emission factors. It is recommended to treat the larger facilities as point rather than area sources especially in the preparation local emission inventories.

### g) Temporal Variability

The temporal resolution of emissions for the mining and rock quarrying, stone processing and sand and gravel processing sectors have been estimated and reported elsewhere (MEP/ORF 1985).

## h) Geographical Variability

Information is readily available to apportion emissions to the provincial level and locations of each major facility (except many of the smaller quarries) are available in various EMR publications.

## i) Point Source Establishments

On the basis of Environment Canada point source listings and EMR publications, the following major producers are operating in Canada:

| Province | Process Type | Plant ID Code | Plant Name | Location |
|---|---|---|---|---|
| Newfoundland | Iron Ore | 100015 | Iron Ore Co. of Canada | Carol Lake |
| | | 100014 | Wabush Mines | Wabush |
| | Silica | 100013 | Dunville Mining Co. | Long Harbour |
| | Crushed Stone | | Newfound Resources | Port-au-Port |
| | | | North Star Cement Ltd. | Corner Brook |
| Nova Scotia | Coal | | Cape Breton Dev. | |
| | | | - Lingan Mine | Lingan |
| | | | - No. 26 Colliery | Glace Bay |
| | | | - Prince Mine | Point Aconi |
| | | | Evans Coal Mine | Inverness |
| | | | Drummond Coal Co. | Westville |
| | | | Thorburn Mining | Stellarton |
| | | | River Hebert Coal | River Hebert |
| | Dimension Stone | | Granitile Inc. | Port Hawksbury |
| | Crushed Stone | | Lone Star Industries | Canso |
| | | | Wallace Quarry | Wallace |
| | Silica | 120023 | N.S. Sand & Gravel | Shubenacadie |
| New Brunswick | Coal | | N.B. Coal Ltd. | Minto |
| | Metals | 130001 | Brunswick M & S | Bathurst |
| | Crushed Stone | | Various quarries | Brookville<br>Bathurst<br>Havelock<br>St. Stephen<br>Sackville |
| | Silica | | Chaleur Silica Ltd. | ? |
| | | | Sussex Silica Inc. | Sussex |
| Quebec | Iron Ore | | Quebec Cartier | Mount Wright |
| | Metals | | BP Resources Ltd. | Joutel |
| | | | Noranda Inc. | Matagami |
| | | | Northgate Mines Inc. | Val-d'Or |
| | Crushed and Building Stone | | Various quarries | Montreal<br>Eastern Townships |

| Province | Process Type | Plant ID Code | Plant Name | Location |
|---|---|---|---|---|
| | | | | Lac St-Jean |
| | | | | Riviere-a-Pierre |
| | | | | Hemingford |
| | | | | Huntingdon |
| | | | Tulinor Inc. | Grandes Berge-ronnes |
| | Silica | | Falconbridge Ltd. | Saint Donat |
| | | | | Saint Cunat |
| | | | Uniquartz Inc. | St. Jean Vianney |
| | | | Hogan Holdings Inc. | Saint Urbain |
| | | | Baskatong | Lac Bouchette |
| | | | Lorna Enterprises Ltd. | Beauport |
| | | | Armand Sicotte Ltd. | St. Clothilde |
| | | | Good Sand Co. | St. Joseph-du-Lac |
| | | | | Ormstown |
| Ontario | Iron Ore | | Adams Mine | Kirkland Lake |
| | | 351332 | Algoma Ore Div. | Wawa |
| | | | Sherman Mine | Temagami |
| | Metals | | Falconbridge Ltd. | Sudbury |
| | | | | Timmins |
| | | | Giant Yellowknife Ltd. | Pamour |
| | | | | Shumacher |
| | | | Inco Ltd. | Sudbury |
| | | | Lac Minerals Ltd. | Marathon |
| | | | Noranda Inc. | Manitouwundge |
| | | | Mattabi Mines Ltd. | Ignace |
| | | | Dome Mine | South Porcupine |
| | Crushed and Building Stone | | Steetley Quarry Products | Dundas |
| | | | Dufferin Aggregates | Milton |
| | | | Gormley Aggregates Ltd. | Gormley |
| | | 351364 | Esso Chemicals | Samia |
| | | 351366 | Fed. White Cement Ltd. | Woodstock |
| | | | Amscraft Corp. | Wiarton |
| | | | Steep Rock Calcite | Tatlock |
| | | | | Perth |
| | | | Nelson Granite Ltd. | Vermilion Bay |
| | | | Canadian Shields Quarries | Sudbury |
| | | | Granimar Quarries | Kingston |
| | Silica | | Falconbridge Ltd. | Badgeley Island |
| | | | | Midland |
| | Nepheline Syenite | | Indusmin Division | Methuen |
| Manitoba | Metals | | Hudson Bay M & S Co. | Flin Flon |
| | | | | Snow Lake |
| | | | | Leaf Rapids |
| | | | Inco Ltd. | Thompson |
| | Crushed and Building Stone | | Gills Quarries | Garson |
| | | | Various quarries | Moosehorn |
| | | | | Mafcking |
| | Silica | | Marine Transport Ltd. | Black Island |
| | | 460024 | Steel Brothers Can. Ltd. | ? |
| | | | Inco Ltd. | Manasan |

| Province | Process Type | Plant ID Code | Plant Name | Location |
|---|---|---|---|---|
| Saskatchewan | Coal | | Man. & Sask. Coal Co. | Bienfait |
| | | | | Esteran |
| | | | Manalta Coal Ltd. | Esteran |
| | | | Utility Coals Ltd. | Esteran |
| | | | Sask. Power Corp. | Esteran |
| | Silica | | Hudson Bay M & S Ltd. | Amisk Lake |
| Alberta | Coal | 480113 | Coleman Colliaries Ltd. | Coleman |
| | | | Canmore Mines Ltd. | Canmore |
| | | 480115 | Cardinal River Coals | Hinton |
| | | 480116 | McIntyre Mines Ltd. | Grande Cache |
| | | 480143 | Luscar-Sterco Ltd. | Edson |
| | | | Manalta Coal Ltd. | Halkirk |
| | | | | Forestburg |
| | | | | Wabamun |
| | | | | Seba Beach |
| | | | | Sheerness |
| | Crushed and Building Stone | | Various quarries | Exshaw |
| | | | | Kananaskis |
| | | | | Crowsnest |
| | | | | Cadomin |
| | | | | Banff |
| | Silica | 480125 | Sil Silica Ltd. | Bruderheim |
| British Columbia | Metals | | Brenda Mines Ltd. | Peachland |
| | | | Broken Hill Proprietary Co. | Port Hardy |
| | | | Cominco Ltd. | Kimberley |
| | | | Gibraltar Mines Ltd. | McLeese Lake |
| | | | Highland Valley Copper | Logan Lake |
| | | | Newmont Mines Ltd. | Princeton |
| | | 59073 | Noranda Inc. (Bell) | Babine Lake |
| | | | Placer Dome Inc. | Houston |
| | | | Teck Corp. | Kamloops |
| | | | Westmin Resources Ltd. | ButtleLake |
| | Coal | | Kaiser Resources Ltd. | Michel Sparwood |
| | | 590051 | Fording Coal Ltd. | Elkford |
| | | | Byron Creek Collieries | Kootenay,Corbin |
| | | 590677 | Ridley Terminals | Prince Rupert |
| | Crushed and Building Stone | | Various quarries | Texada Island |
| | | | | Terrace |
| | | | | Clinton |
| | | | | Westwold |
| | | | | Popkum |
| | | | | Dahl Lake |
| | | | | Doeye River |
| | | | | Cobble Hill |
| | | 590721 | Steel Bros. Can. Ltd. | Cache Creek |
| | | | B.C. Granite Ltd. | Vancouver |
| | Silica | | Mountain Minerals Co. | Golden |

| Province | Process Type | Plant ID Code | Plant Name | Location |
|---|---|---|---|---|
| Yukon | Metals | | Curragh Resources Corp. | Faromine |
| North West Territories | Metals | | Cominco Ltd. | Little Cornwallis Island |

It should be noted that several other smaller producers have not been included in this list. The locations of other mineral mines and processing operations (e.g. gypsum, asbestos, salt and potash) have been identified in other sections.

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## A.10.1 BAKERIES (SIC 10720)

### a) General Description

In the baking industry, VOCs are released by the leavening process. Emissions from products leavened by baking powder (used mainly for pastries) are negligible. However, hydrocarbons are released when yeast is used for leavening. Yeast is used nearly exclusively in the production of bread and bread-like pastries. (Environment Canada 1983)

### b) Sector Description

The straight-dough and the sponge-dough are the two main processes used in the commercial production of bread. In the straight-dough process, fermentation occurs after all ingredients are mixed. Sponge-dough is fermented with just part of the ingredients; the remaining ingredients are added and ferment just prior to baking. The fermentation process takes from 2-4 hours. Oven temperatures are generally around 230°C. Any vapours from the bread baking or due to combustion (usually natural gas) are generally removed through the same vent. (U.S. EPA 1985, Environment Canada 1983)

Although carbon dioxide is produced during fermentation, it remains in the bread. Ethanol is released to the atmosphere during both the fermentation and baking stages. (Environment Canada 1983)

No controls or process modifications are used to reduce ethanol emissions from bakeries. (Environment Canada 1983)

The SCC for bakeries is 51000.

### c) Inventory Approach

Bakeries are inventoried as area sources of VOCs (ethanol) using emission factors based on the weight of bread produced.

### d) Preferred Emission Estimation Procedure

Emission factors for each of the bread-making processes are available in AP-42 (U.S. EPA 1985) or in the 1985 NAPAP inventory point source emission factor listing under SCC 3-02-032-XX (U.S. EPA 1987).

If details on the relative amounts of straight-dough and sponge-dough bread are not available, the emission factors can be combined using a 1:3 ratio (Edwards and Cotton 1988).

### e) Activity Level

Bread production statistics are available in Statistics Canada's annual report (since 1985) "Bread and Other Bakery Products Industry".

### f) Alternative Emission Estimation Procedures

Very large bakeries could be inventoried as point sources of VOCs under SCC 3-02-032-XX. Bread production for these sources would then have to be subtracted from the area source base quantities.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors for bakeries are given in MEP and ORF (1985).

### h) Geographical Apportionment

Geographical apportionment of the production data may be based on sector employment or population data.

### i) Point Source Establishments

## References - Section A.10.1

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## A.25.1 SAWMILLS (SIC 25120)

### a) General Description

This sector involves the debarking and sawing of logs into lumber, with associated surface finishing operations. The only emission of concern with these operations is particulate matter. Emissions of particulate matter, $SO_x$, $NO_x$, VOC and CO related to the combustion of wood and wood waste in boilers associated with the sawmill operations are inventoried separately. Any emissions associated with other fuel combustion are inventoried with industrial fuel combustion (SIC 56223).

### b) Process Description

Sawmills, in most of Canada, are normally described using a single area source SCC: 57100.

There are process-specific, point source SCCs available to describe the different steps used in a sawmill operation:

| | |
|---|---|
| 3-07-008-01 | Log Debarking |
| 3-07-008-02 | Log Sawing (fugitive) |
| 3-07-008-03 | Sawdust Pile Handling |
| 3-07-008-04 | Sawing: Cyclone Exhaust |
| 3-07-008-05 | Planing/Trimming: Cyclone Exhaust |
| 3-07-008-06 | Sanding: Cyclone Exhaust |
| 3-07-008-07 | Sanderdust: Cyclone Exhaust |
| 3-07-008-08 | Other Cyclones: Exhaust |

Sawmills in British Columbia are inventoried as point sources using the point SCCs as listed above.

### c) Inventory Approach

The preferred method of emission estimation is the use of permit data to characterize fugitive and controlled process emissions as point sources. However, this is currently only done for British Columbia. For the remainder of Canada, current practice is to inventory sawmills as area sources using particulate matter emission factors based on production data.

## d) Preferred Emission Estimation Procedure

As stated above in c), the preferred emission estimation method is to use site-specific source/permit data and inventory sawmills as point sources. If emission characterizations are not available, each site could be characterized on the basis of production rates and pollution control equipment. AP-42 (U.S. EPA 1985) provides fugitive particulate matter emission factors for: log debarking and sawing, based on the weight of logs processed; and sawdust handling, based on the weight of sawdust handled. Particulate matter emission factors for woodworking operations (i.e., sawing, planing and sanding in a sawmill) that are controlled with a cyclone (i.e., other than fugitive), are also provided in AP-42 (U.S. EPA 1985). However, these emission factors are based on the airflow of the cyclone or given as typical emission rates per hour.

## e) Activity Level

If the preferred inventory method is used, activity level data (tonnes logs processed and sawdust handled and SCFM of cyclone operation) is obtained from operating permits.

Madison's Canadian Lumber Directory (annual) lists, by province, the manufacturers and production rates. This information could be used to check that the list of manufacturers obtained from permit data is complete and to fill in missing data by prorating from similar operations, and balancing provincial production totals against those in the directory.

Another potential source of annual production rates is Statistics Canada publication number 35-250B. Wood Industries 2511 (Shingle and Shale Industry) and 2512 (Sawmill and Planing Mill Products Industry (except Shingles and Shales)), which when used in conjunction with price indices (from?) provide annual production rates by province.

### f) Alternative Emission Estimation Procedure

If sawmills are to be inventoried as area sources, some emission factor development work must be done as available emission factors from AP-42 (U.S. EPA 1985) are tailored to inventorying this sector as point sources.

One method of doing this is to characterize typical cyclone requirements and sawdust production for a given log processing rate, and using this information to estimate an overall emission factor that includes all fugitive and controlled particulate matter emission sources as discussed above.

Alternatively, the B.C. detailed inventory could be used to relate typical particulate matter emission rates to log processing or production rates.

### g) Temporal Variability

Hourly, daily and seasonal temporal factors for this sector are available in a report by The MEP Company and Ontario Research Foundation (1985).

### h) Geographical Variability

Producers are identified in Madison's Canadian Lumber Directory (annual). Provincial production rates are also available from Statistics Canada (annual).

### i) Point Source Establishments

Point sources currently listed under sawmills on the Residual Discharge Inventory System maintained by Environment Canada are as follows:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351342 | Great West Timber | Thunder Bay |

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| British Columbia | 590210 | Ainsworth Lumber Co. Ltd., Chasm Div. | Clinton |
| | 590211 | Ainsworth Lumber Co. Ltd., Exeter Div. | 100 Mile House |
| | 590218 | Apollo Forest Products Ltd. | Fort St. James |
| | 590222 | Aspen Planers Ltd. | Merritt |
| | 590239 | B.C. Forest Products Ltd. | Maple Ridge |
| | 590240 | B.C. Forest Products Ltd. | Boston Bar |
| | 590238 | B.C. Forest Products Ltd. | Victoria |
| | 590236 | B.C. Forest Products Ltd. | MacKenzie |
| | 590237 | B.C. Forest Products Ltd. | Youbou |
| | 590229 | Babine Forest Products Ltd. | Burns Lake |
| | 590232 | Balco Industries Ltd., Fadear Creek Div. | Louis Creek |
| | 590230 | Balco Industries Ltd., Nicola Div. | Merritt |
| | 590261 | Balfour Forest Products | Bear Lake |
| | 590260 | Balfour Forest Products | Taylor |
| | 590259 | Balfour Forest Products, Clear Lake Mill | Prince George |
| | 590263 | Brisco Wood Preservers | Brisco |
| | 590280 | Canadian Forest Products Ltd. | Fort St. John |
| | 590279 | Canadian Forest Products, Chetwynd Mill | Chetwynd |
| | 590289 | Carrier Lumber Ltd. | Prince George |
| | 590322 | Clearwater Timber Products Ltd. | Clearwater |
| | 590323 | Clearwater Timber Products Ltd. | Vavenby |
| | 590321 | Clearwater Timber Products Ltd. | Valemount |
| | 590353 | Crestbrook Forest Industries | Canal Flats |
| | 590352 | Crestbrook Forest Industries | Elko |
| | 590350 | Crestbrook Forest Industries Ltd. | Cranbrook, |
| | 590354 | Crown Forest Industries Ltd. | Lumby |
| | 590357 | Crown Forest Industries Ltd. | Armstrong |
| | 590356 | Crown Forest Industries Ltd. | Kelowna |
| | 590369 | Decker Lake Forest Products | Burns Lake |
| | 590382 | Dunkley Lumber Ltd. | Prince George |
| | 590405 | Evans Products Co. Ltd. | Donald Station |
| | 590404 | Evans Products Co. Ltd. | Lillooet |
| | 590413 | Federated Cooperatives Ltd. | Canoe |
| | 590414 | Federated Cooperatives Ltd. | Revelstoke |
| | 590417 | Finlay Forest Industries | MacKenzie |
| | 590455 | Holding Lumber Co. Ltd. | Chase |
| | 590458 | Houston Forest Products Company | Houston |
| | 590487 | J.H. Huscroft Ltd. | Erickson, |
| | 590484 | Jacobson Bros. Forest Products | Williams Lake |
| | 590522 | L & M Lumber Ltd. | Vanderhoof |
| | 590512 | Lakeland Mills | Prince George |
| | 590516 | Lavington Planer Mill Limited | Lavington |
| | 590520 | Lignum Ltd. | Williams Lake |
| | 590557 | MacMillan Bloedel Ltd. | Nanaimo |
| | 590555 | MacMillan Bloedel Ltd. | Port Alberni |
| | 590570 | Nechako Lumber Co. Ltd. | Vanderhoof |
| | 590258 | Netherlands Overseas, Balfour For.Prod. | Prince George |
| | 590578 | Northwood Pulp & Timber Ltd. | Houston |
| | 590581 | Northwood Pulp & Timber Ltd. | Shelley |
| | 590580 | Northwood Pulp & Timber Ltd. | Upper Fraser |
| | 590635 | Pinnette & Therrien Mills Ltd. | Williams Lake |
| | 590652 | Pope & Talbot Ltd. | Grand Forks |
| | 590653 | Pope & Talbot Ltd. | Midway |

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| | 590630 | Prince George Precut Ltd. | Prince George |
| | 590647 | Prince George Wood-Preserving | Prince George |
| | 590663 | Raven Lumber Ltd. | Campbell River |
| | 590675 | Revelstoke Sawmill (Radium) Ltd. | Radium Hot Springs |
| | 590679 | Riverside Forest Products Ltd. | Lumby |
| | 590689 | Rustad Bros. & Co. Ltd. | Prince George |
| | 590703 | Skeena Sawmills | Terrace |
| | 590706 | Slocan Forest Products Ltd. | Slocan |
| | 590708 | Sooke Forest Products Ltd. | Sooke |
| | 590720 | Starline Cedar Mills Ltd. | Williams Lake |
| | 590722 | Stege Logging Ltd. | New Hazelton, |
| | 590735 | Takla Forest Products, Div. of Canfor | Fort St. James, |
| | 590734 | Takla Forest Products, Div. of Canfor | Isle Pierre |
| | 590611 | The Pas Lumber Co. Ltd. | Prince George, |
| | 590612 | The Pas Lumber Co. Ltd., Hart Sawmill | Bear Lake |
| | 590793 | Weldwood of Canada Ltd. | Squamish |
| | 590792 | Weldwood of Canada Ltd. | Williams Lake |
| | 590791 | Weldwood of Canada Ltd. | 100 Mile House, |
| | 590808 | West Fraser Mills Ltd. | Chetwynd |
| | 590810 | West Fraser Mills Ltd. | Lejac |
| | 590809 | West Fraser Mills Ltd., Pac. Inland Res. | Smithers |
| | 590795 | Westar Timber Limited, Hazelton Lumber | South Hazelton |
| | 590798 | Westar Timber Ltd., Celgar Lumber | Castlegar |
| | 590797 | Westar Timber Ltd., Kitwanga Lumber | Kitwanga |
| | 590796 | Westar Timber Ltd., Plateau Operations | Vanderhoof |
| | 590804 | Weyerhaeuser Canada Ltd. | Lumby |
| | 590805 | Weyerhaeuser Canada Ltd. | Merritt |
| | 590803 | Weyerhaeuser Canada Ltd. | Okanagan Falls |
| | 590801 | Weyerhaeuser Canada Ltd. | Vavenby |
| | 590806 | Weyerhaeuser Canada Ltd.,Princeton Div. | Princeton |
| | 590812 | Whonnock Lumber Company Ltd. | Whonnock |
| | 590827 | Zeidler Forest Industries Ltd. | McBride |

## References - Section A.25.1

Madison's, annual "Canadian Lumber Directory". Vancouver, B.C.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for the 1980 National Anthropogenic Area Source Emissions". Prepared for Supply and Services Canada.

Statistics Canada, annual. "Wood Industries. Shingle and Shale Industry". Catalogue No. 35-250B 2511.

Statistics Canada, annual. "Wood Industries. Sawmill and Planing Mill Products Industry (Except Shingle and Shales)". Catalogue No. 35-250B 2512.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume 1 Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.25.2 PLYWOOD AND VENEER (SIC 25200)

### a) General Description

Plywood is composed of thin layers of wood (veneers) bonded together with an adhesive. The outer layers (faces) surround a core which is usually lumber, veneer or particleboard. Most plywood is made from Douglas Fir or other softwood. (Environment Canada 1983, U.S. EPA 1985)

Principal emissions from this sector are VOCs and particulate matter. (Environment Canada 1983)

### b) Process Description

In the production of plywood, logs are sawed to the required length, debarked and peeled into veneers of uniform thickness. These veneers are then put into dryers to reduce their moisture content. After drying, veneers go into a layout operation, where they are sorted, patched and layered and a thermosetting resin adhesive applied. The veneer assembly is then transferred to a hot press where the pressure and steam form the product. Final processing involves trimming, face sanding and possibly use-specific finishing treatments. (U.S. EPA 1985)

VOC emissions occur primarily during the product drying stage, though some also occur while curing plywood in the pressing stage. These emissions originate primarily from evaporation of natural organic oils present in the wood and due to the operation of the dryer (particularly gas-fired) and, to a lesser extent, from the synthetic resins used. Therefore, the quantity and type of organics emitted vary depending on the wood species and on the dryer type and its method of operation. Controls are not usually installed to limit VOC emissions. (Edwards and Cotton 1988)

Particulate matter emissions arise from log sawing, debarking, veneer cutting and plywood cutting and sanding operations. The dust that escapes into the air from sanding, sawing and other wood-working operations may be controlled by collection in an exhaust system and transported through duct work to a sized cyclone. Particulate matter emissions from the veneer dryers are considered negligible.

When inventoried as area sources, plywood and veneer manufacturing is grouped under a single SCC: 57200.

The following SCCs, used for point source designations, may be used to describe the pertinent aspects of plywood and veneer manufacture:

| | |
|---|---|
| 3-07-007-01 | General, not classified |
| 3-07-007-02 | Sanding operations |
| 3-07-007-05 | Hardboard: Coe Dryer |
| 3-07-007-05 | Hardboard: Predryer |
| 3-07-007-06 | Hardboard: Pressing |
| 3-07-007-07 | Hardboard: Tampering |
| 3-07-007-09 | Hardboard: Bake Oven |
| 3-07-007-10 | Fir - Sapwood - Steam-Fired Dryer |
| 3-07-007-12 | Fir - Sapwood - Gas-Fired Dryer |
| 3-07-007-13 | Fir - Heartwood Plywood Veneer Dryer |
| 3-07-007-14 | Larch Plywood Veneer Dryer |
| 3-07-007-15 | Southern Pine Plywood Veneer Dryer |

## c) Inventory Approach

The preferred inventory approach for the plywood and veneer industry is to treat each producer as a point source and base VOC and particulate emissions on either site-specific source/permit data or a combination of site-specific operations/permit data and emission factors from AP-42 (U.S. EPA 1985) or NAPAP (U.S. EPA 1987).

Alternatively, the inventory may be prepared using area source techniques based on emission factors, production information and area-specific characterizations of wood type and drying systems. The latter requirement is fairly labour intensive. However, this level of base quantity characterization is necessary in order to be able to use the emission factors available (see above), as they have been derived for use in point source inventories.

### d) Preferred Emission Estimation Procedure

The preferred emission estimation methods for point and area source inventory were described above. British Columbia currently uses the point source method, while other provinces use the area source methodology.

### e) Activity Level (Edwards and Cotton 1988)

To calculate the emissions, a breakdown of production by wood species and drying system for each province must be conducted. General statistics are available from Statistics Canada; however, a complete breakdown will require review of other information sources. Provincial Ministry of Environment departments should have data pertaining to the type of dryer present at each facility through emissions permit data and other statistical data. The amount of production attributed to each drying system can be obtained using plant capacity for each system.

Information on production by wood species are available from several sources, including journals and industry associations. The annual Directory of the Forest Products Industry, published by the Forest Products Journal, provides locations, plant capacity and major wood species for each mill. Similar data is available from associations or publications such as Madison's Canadian Lumber Directory. Using data presented by these associations for wood species and plant capacity in conjunction with provincial production data from Statistics Canada (catalogue No. 35-250-2520) should provide sufficient base quantity values to allow use of published emission factors.

Where difficulty in obtaining species data for the industry arises, the production values can be apportioned based on total forest harvest data. This data is available from provincial and federal forestry and resource ministries.

### f) Alternative Emission Estimation Procedure

The area source inventory procedure described above is the preferred area source method. Alternatively, if it is not possible to characterize the local industry in enough detail to use this method, the British Columbia point source inventory could be used to derive typical emission factors, by wood type, for particulate matter and VOCs.

### g) Temporal Variability

Hourly, daily or seasonal temporal factors for the plywood and veneer industry are available in a report by The MEP Company and Ontario Research Foundation (1985).

### h) Geographical Variability

Area source production data is available on a provincial basis..

### i) Point Source Establishments

The following point sources are currently listed by Environment Canada on their Residual Discharge Inventory System:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| British Columbia | 590233 | Balco Industries Ltd., Heffley Div. | Kamloops |
| | 590351 | Crestbrook Forest Industries | Creston |
| | 590406 | Evans Products Co. Ltd. | Golden |
| | 590407 | Evans Products Co. Ltd. | Savona |
| | 590556 | MacMillan Bloedel Ltd. | Port Alberni |
| | 590582 | Northwood Pulp & Timber Ltd., NCP | Prince George |
| | 590733 | Tackama Forest Products Ltd. | Fort Nelson |
| | 590763 | Victoria Plywood Cooperative | Victoria |
| | 590790 | Weldwood of Canada Ltd. | Quesnel |

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Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd. for Environmental Analysis Branch, Environment Canada.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Madison's annual. "Canadian Lumber Directory". Vancouver, B.C.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Prepared for Supply and Services Canada.

Statistics Canada, annual. "Wood Industries, Veneer and Plywood Industries". Catalogue No. 35-250B-2520.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory". EPA/600/7-87/015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.27.1 SULPHATE (KRAFT) PULPING (SIC 27110)

### a) General Description

All of the common air pollutants are released in significant quantities from the various chemical recycling processes involved in Kraft pulping. After wood chips are pressure-digested and washed, the wood pulp is bleached and dried to the finished product. The spent cooking liquor, containing process chemicals, dissolved organics and water from the wood, is treated and combusted for chemical recovery where most emissions occur (i.e., particulates, $SO_2$, $NO_x$, HC, CO and other contaminants).

### b) Process Description

The various types of emissions associated with Kraft pulping are released from the following sources common to most pulp mills.

Washers/Screens (SCC 3-07-001-02):
Small amounts of $SO_2$ and HC are emitted during separation of the spent liquor and washing of the brown stock pulp after digestion. Non-condensible gases may be vented to the lime kiln or recovery boiler and other exhaust gases are usually uncontrolled.

Turpentine Condenser (SCC 3-07-001-07):
The relief gases from the digester are condensed in part to form turpentine after decanting, which releases small amounts of uncontrolled HC.

Multiple Effect Evaporator (SCC 30-7-001-03):
Small quantities of $SO_2$ may be emitted as water from the spent pulping liquor (black liquor) is evaporated unless vented to the recovery furnace.

Liquor Oxidation Tower (SCC 3-07-001-09):
Exhaust gases containing $SO_2$ and HC are emitted from the oxidation tower as air is blown into the liquor for oxidation and further solids concentration.

Recovery Furnace/Direct Contact Evaporator (SCC 3-07-001-04):
In conventional processes, the black liquor is further concentrated to ~65% solids (U.S. EPA 1986) in a direct contact evaporator by contact with recovery furnace flue gases. The strong black liquor is then burned in a recovery furnace where the organics content supports combustion, the inorganic salts are converted for recycling and heat is recovered. This operation represents the strongest sources of all the common pollutants and emissions are usually controlled by an ESP or sometimes a venturi scrubber, either of which may be backed by an auxiliary scrubber. Some newer mills have replaced the direct contact evaporator by extending the multiple evaporation stage which effectively reduces $SO_2$ emissions from this process (U.S. EPA 1986).

Smelt Dissolving Tank (SCC 3-07-001-05):
All pollutants but CO are emitted in this process in which the molten inorganic chemicals from the recovery furnace are dissolved in water to form green liquor. Particulate emissions can be reduced somewhat with mesh pad controls, which are commonly used while both particulate and $SO_2$ emissions are reduced more effectively with exhaust scrubbers.

Lime Kiln (SCC 3-07-001-06):
Lime is calcined in a kiln or other unit to provide quicklime for converting the green liquor in a causticizing tank to the digester liquor. Emissions of particulate, $SO_2$, $NO_x$, HC and CO from the lime kiln can be partially controlled with a scrubber and other process controls.

Fluid Bed Calciner (SCC 3-07-001-08):
Some pulp mills may utilize a fluid bed reactor to calcine the lime. Emissions are similar to those from the lime kiln.

Auxiliary Steam and Power Boilers (SCC 1-02-009-01 to 06):
Another major source of emissions in a Kraft mill are boilers used to generate electrical power and steam. The fuels used are coal, oil and natural gas, as well as bark or wood waste. The use of wood waste as a fuel in boilers is generally exclusive to the wood products industry.

### c) Inventory Approach

Inventories of pulp mill emissions are best compiled using Point Source Methods, since practically all mills have been estimated to emit greater than 100 tonnes $SO_2$ per year (Environment Canada 1983, Johnson 1987) and most can be expected to emit HC in excess of this amount (Edwards and Cotton 1988). Emission factors and/or direct source test data are most often used to estimate emissions from Kraft pulping processes, since sulphur or other material balances are impractical.

### d) Preferred Emission Estimation Procedure

Information sources that can be used to calculate emissions for each of the pollutants include:

- specific emission factors developed and reported by Environment Canada based on survey data (Environment Canada 1979, 1982, 1983a and b, 1985),
- AP-42 emission factors (U.S. EPA 1986),
- NAPAP Inventory Emission Factors (U.S. EPA 1987),
- NCASI Technical Bulletins #105, 112, 358 and 371 (NCASI).

In order to compile accurate emissions and procure appropriate data, it is strongly recommended to directly contact the individual producers. Any relevant emission test measurements should be obtained that might update existing survey data on $SO_2$ and $NO_x$ and should be used in preference to emission factors as long as data can be verified or adequately checked from process information. However, it has been reported that virtually no VOC emission test data are available (Edwards and Cotton 1988). Hence, in most instances, the use of emission factors will be required for those sources in which plant-specific emissions data are unavailable. The best sources for obtaining these emission factors at the process (SCC) level are AP-42 and the NAPAP listing. It is recommended to use AP-42 for determining particulate, CO and most of the $SO_2$ emissions, since information related to control device reductions and efficiencies is reported. For $NO_x$, HC and specific $SO_2$ processes (SCC 3-07-001-08 to 10), NAPAP factors have been consolidated and summarized. Many of these factors have been derived from discussions with mill personnel and emissions surveys conducted in the U.S. by the National Council on Air and Stream Improvement for the Pulp and Paper Industry (NCASI). The emission factors are reported in kg/tonne (or lb/ton) of air dried unbleached pulp. Similarly, emission factors for wood/bark-fired boilers (in units of lb/ton burned) are reported in the summarized NAPAP emission factor listing according to sizes of boilers (i.e., steam capacity rating).

### e) Activity Level

Plant production data can be obtained from:

- Environment Canada files based on information supplied by companies as part of their compliance with clean water regulations (Environment Canada 1986)
- the Canadian Pulp and Paper Association
- and capacity information by plant (e.g., Lockwood's Directory 1989) or other Canadian trade journals (Pearson 1987)

However, it is recommended to contact individual mills, in order to obtain relevant base quantity and operating data, process information pertinent to source identification, specific controls and any emissions data that may be available. The requested data should include as a minimum:

- the amount of pulp produced (i.e., weight of air dried unbleached pulp) with corrections where necessary on amounts of bleaching additives (e.g., 5 to 12%) for plants producing semi-bleached pulp (Edwards and Cotton 1988),
- process specific production data in cases where different emission characteristics could occur for multiple source units,

- the number, types and scheduling of recovery boilers in operation which may require apportionment of base quantities accordingly, where units differ or where specific sources do not process all of the spent liquor generated,
- the usage, type and removal efficiency for pollution control devices associated with pertinent operations,
- fuel types and consumption for boilers, plant power and other heaters (including quantities of wood waste),
- pertinent emissions data.

It is recommended to include power boiler fuel consumption as a source of air pollutants at pulp mills, since much of the fuel used (e.g., wood waste) is specific to this industry. In this case, fuel totals (by fuel type) should be deducted from those compiled in the industrial fuel combustion area source sector (see Section B.56). Once plant production data are available, emissions can be readily calculated by applying reported emission factors. Apart from incorporating fuel combustion emissions with this sector, Environment Canada has normally used the above approach in previous inventories with data that have been consolidated from surveys pertaining to $SO_2$ and $NO_x$ emission factors and with production data obtained through regulatory requirements. However, it has been noted that some discrepancies may exist in the reported production data (Edwards and Cotton 1988).

### f) Alternative Emission Estimation Procedures

In instances where less accurate emissions data are required than previously discussed, or insufficient resources are available to contact plants, alternative emission estimates can be derived using published information. For example, the chemical recovery boiler is known to be the primary source of sulphur dioxide, HC and particulate emissions at most plants. On a long term basis, it is reported that other combined sources normally account for less than 6% of the total $SO_2$ emissions from Kraft pulping (U.S. EPA 1985). However, alternative estimates of $SO_2$, $NO_x$ and HC should account for, at minimum, the significant process contributions such as: the recovery boilers, smelt dissolving tanks, lime kilns, liquor oxidation towers and other miscellaneous processes for which emission factors are available (U.S. EPA 1986, 1987). Related fuel combustion emissions (i.e., steam and power boilers) could be accounted for in the collective area source industrial fuel combustion sector. Production data, based on nominal pulp capacities, or average production rates, can be acquired from producer directories and trade journals (Lockwood 1989, Pearson 1987). These compilations also provide information on the plant identification, contacts, the type of process equipment at each facility (e.g., digesters, evaporators, recovery furnaces, etc.) and the types of control devices installed.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors by province have been estimated and reported for the Kraft pulping sector (MEP/ORF 1985).

### h) Geographical Variability

By compiling emissions on a point source basis, the actual plant locations will be reported.

### i) Point Source Establishments

The following list of Kraft pulping plants has been assembled from Environment Canada's Inventory System point source listing (1990) and other information (Lockwood Directory 1989). Information on stack parameters for most plants is also available in files of the Inventory Management Division at Environment Canada.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Nova Scotia | 120002 | Scott Maritimes Pulp Ltd. | New Glasgow |
| New Brunswick | 130005 | Boise Cascade Canada Ltd. | |
| | 130003 | Consolidated-Bathurst Ltd. | Bathurst |
| | 130004 | Irving Pulp and Paper Ltd. | Saint John |
| | 130006 | St. Anne Nackawic Pulp & Paper Co. | Nackawic |
| | | Miramichi Pulp & Paper Inc. | Newcastle |
| Quebec | 240119 | Cascades (East Angus) Inc. | East Angus |
| | 240120 | Cascades (Jonquiere) | Jonquiere |
| | 240029 | CIP Inc./La Tuque | La Tuque |
| | 240030 | Consolidated Bathurst Inc. (Div.Chaleurs) | New Richmond |
| | 240031 | " " " (Div. Pontiac) | Portagedu Fort |
| | 240032 | " " " (Div. Wayagamac) | Trois Rivieres |
| | 240035 | Domtar Inc./Level sur Quevillon | Lebel sur Quev. |
| | 240123 | Donohue St.-Felicien Inc. | St.-Felicien |
| | 240126 | Industries James MacLaren Inc. | Thurso |
| | 240033 | Papiers Fin Domtar | Windsor |
| Ontario | 351352 | Boise Canada | Kenora |
| | 351324 | Domtar Fine Papers | Cornwall |
| | 351353 | Domtar Packaging Ltd. | Red Rock |
| | 351336 | Eddy Forest Products | Espanola |
| | 351355 | Canadian Pacific Forest Products Ltd. | Dryden |
| | 351354 | " " " " " | Thunder Bay |
| | 351344 | James River Marathon | Marathon |
| | 351356 | Kimberly-Clark Can. | Terrace Bay |
| | 351335 | Malette Kraft P & P | Sault St. Marie |
| Manitoba | 460007 | Manitoba Forest Resources Ltd. | The Pas |
| Saskatchewan | 470003 | Prince Albert P & P. | Prince Albert |
| Alberta | 480165 | Champion Forest Products (Weldwood) | Hinton |
| | 480008 | Proctor & Gamble Cellulose Ltd. | Grand Prairie |
| | 480007 | St. Regis (Alta.) Ltd. | |
| British Columbia | 590235 | BC Forest Products Ltd. | Mackenzie |
| | 590235 | " " " " | Crofton |
| | 590011 | Canadian Forest Products Ltd. | Prince George |
| | 590012 | Cariboo P & P C. | Quesnel |
| | 590013 | Crestbrook P & P Ltd. | Skookumchuck |
| | 590014 | Crown Zellerback Can. Ltd. | Campbell River |
| | 590015 | Eurocan P & P Co. Ltd. | Kitimat |
| | 590016 | Intercontinental Pulp Co. (Can. For. Prod.) | Prince George |
| | 590018 | MacMillan Bloedel (Alberni Div.) | Port Albert |
| | 590017 | " " (Harmac Div.) | Nanaimo |
| | 590019 | " " (Powell Riv. Div.) | Powell River |
| | 590020 | Northwood Pulp Ltd. | Prince George |
| | 590021 | Prince George P & P Ltd. (Can. For. Prod.) | Prince George |
| | 590025 | Western Forest Products | Squamish |
| | 590024 | Weyerhaeser Canada Ltd. | Kamloops |
| | | Celgar Pulp Co. | Castlegar |
| | | Howe Sound P & P Co. | Port Mellon |
| | | Canadian Pacific Forest Products | Gold River |
| | | Skeema Cellulose Inc. | Prince Rupert |

## References - Section A.27.1

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## A.27.2 SULPHITE PULPING (SIC 27111)

### a) General Description

Acid sulphite pulping operations produce a relatively small fraction of total pulp production in Canada, but represent a significant source of sulphur dioxide emissions. In the process, wood chips are digested under high pressure and temperature with sulphurous acid solution that is buffered with bisulphites of sodium, magnesium, calcium or ammonium. The cooking liquor is usually produced by burning sulphur in a rotary or spray burner and absorbing the sulphur dioxide in the alkaline solution. The chemicals in the spent sulphite liquor may be recovered for reprocessing in some plants (i.e., sodium and magnesium based operations), while other systems require an acid plant to supply the sulphite requirement (Environment Canada 1979, U.S. EPA 1986), Most Canadian plants are sodium based (Johnson 1987, Lockwood's Directory 1989).

### b) Process Description

Although operations may differ substantially between mills, the following operations are the most common sources of $SO_2$ emissions.

Digester/Blow Pit/Dump Tank (SCC 3-07-002-11 to 15):
Intermittent emissions occur with digester relief gases during batch or continuous pulping and most occur while discharging the cooking liquor into a blow pit by either high pressure discharge or pumping. The magnitude of $SO_2$ emissions depends on the pH of the cooking liquor, the discharge mechanism (i.e., blowing or pumping), the efficiency of the emission control device (i.e., normally scrubber controlled) and whether or not exhaust gases are vented through a recovery system (e.g., MgO process).

Recovery System (SCC 3-07-002-21 to 23):
Where chemical and heat recovery is practiced, the spent sulphite liquor containing dissolved organic solids is concentrated in multiple effect and

direct contact evaporators and then sprayed into a furnace. Upon burning magnesium base liquor, the magnesium oxide produced is slaked and circulated to venturi scrubbers, in order to absorb flue gas $SO_2$ and form the cooking acid. Similarly, burning of sodium base liquor forms a molten smelt which is processed further to adsorb $SO_2$ from recovery furnace flue gases and sulphur burners. Usually emissions are released at only one point in the closed loop system which includes emissions from the recovery furnace, direct contact evaporator, multiple effect evaporator, acid fortification tower and $SO_2$ absorption scrubbers. Hydrocarbon and particulate emissions can also be released from the recovery furnace.

Knotters/Washers/Screens (SCC 3-007-02-34):
$SO_2$ emissions are also known to occur during various miscellaneous operations such as: pulp washing, screening and cleaning.

## c) Inventory Approach

Point source methods should be used to estimate sulphite pulp mill emissions since all existing plants normally emit greater than 100 tonnes $SO_2$ per year (Environment Canada 1983b, Johnson 1987). Most emission estimates have been based upon long-term average emission factors derived from source testing since sulphur balances are anticipated to be less certain due to solution pH dependencies, intermittent and/or batch operations).

## d) Preferred Emission Estimation Procedure

Information sources that can be used to estimate emissions include:

- emission factors reported by Environment Canada (Environment Canada 1979, 1983a and b, Johnson 1987)
- AP-42 emission factors (U.S. EPA 1986)
- NAPAP Inventory emission factors (U.S. EPA 1987)

Because of the various processes used, upgrading and conversions from chemical to mechanical pulping systems, it is recommended to contact individual plants in order to accurately calculate emissions or to procure any available measured emissions data. However, in most instances, the use of emission factors will be required for sources in which plant-specific emissions data are lacking. Sulphur dioxide emission factors at the SCC level have been reported in a study conducted for Environment Canada (Johnson 1987), in a previous national inventory (Environment Canada 1983b), and are available in AP-42 (U.S. EPA 1986). Recovery furnace HC emissions have been reported for the NAPAP inventory (U.S. EPA 1987). Particulate emission factors are also reported in AP-42 (U.S. EPA 1986) and NAPAP documentation (U.S. EPA 1987). It should be recognized that none of the above-mentioned emission factors have been updated in recent years and significant differences may occur for plants that have updated processes to reduce emissions or implemented specific controls.

The selection and application of the most appropriate emission factors should be done after procuring relevant plant operational data such as:

- direct emission measurements for specific processes (e.g., source test or continuous monitoring data), or best estimate of emissions by the producer,
- methods of digester discharge and other process changes used to reduce emissions (e.g., relieving digester pressure before discharge, pumping rather than blowing digester contents, digester venting procedures used, raising cooking liquor pH prior to discharge as a method to lower free $SO_2$ in solution),
- the usage, type and removal efficiency of $SO_2$ scrubbing devices,
- the frequency and effect of purging SSL recovery systems, where used, and identification of components associated with the closed loop chemical recovery system,
- the use and extent of sulphur burning requirements,
- emissions associated with miscellaneous or peripheral plant operations and methods of emission control (e.g., washers, screens, sludge incineration).

## e) Activity Level

Individual plant production data can be obtained from:

- Environment Canada files based on company information supplied in compliance with clean water regulations (Environment Canada 1986),
- statistical tabulations by the Canadian Pulp and Paper Association,
- capacity information by plant in directories or other Canadian trade journals (e.g., Lockwood's Directory 1989).

However, it is recommended to contact individual mills in order to obtain relevant base quantity data and process information according to the sources at the plant in terms of tonnes of air dried and unbleached pulp produced, as well as frequency of operations (e.g., batch or continuous production, daily average of pulp produced by one or more digester for a given absorption tower). Accordingly, emissions can be readily calculated using plant production data and reported emission factors.

## f) Alternate Emission Estimation Procedures

The above-mentioned published emission factors and plant capacity information could be used to readily estimate emissions in cases where insufficient resources are available to directly contact plants. As a guide, the following average emission factors have been used by Environment Canada for emission estimates: 22.5 kg $SO_x$/tonne air dried pulp for acid sulphite plants with chemical recovery as well as bisulphite plants with and without recovery; whereas, a factor of 43.5 kg $SO_x$/tonnes air dried pulp for acid sulphite plants without chemical recovery (Environment Canada 1983b).

## g) Temporal Variability

Seasonal, daily and hourly temporal factors for the sulphite pulping sector have been estimated and reported to Environment Canada (MEP/ORF 1985).

## h) Geographical Variability

Actual point source locations will be available by compiling emissions on a point source basis.

## i) Point Source Establishments

The following list of sulphite pulping mills has been assembled from Environment Canada's Inventory System point source listing (1990) and other information (Lockwood's Directory 1989). Information on stack parameters for most plants is also available in files of the Inventory Management Division of Environment Canada.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Newfoundland | 100001 | Abitibi Price (Groundwood?) | Stephenville |
| | 100002 | Cornerbrook P & P | Cornerbrook |
| | 100003 | Price P & P | Grand Falls |
| Nova Scotia | 120003 | Bowater Mersey Paper Co. | Liverpool |
| | 120004 | Stora Forest Industries | Port Hawkesbury |
| New Brunswick | 130008 | Frazer Co. Ltd. | Atholville |
| | 130007 | Frazer Co. Ltd. | Edmundston |
| | 130009 | N.B. International Paper* (Chemi Mech?) | Dalhousie |
| | | Consolidated Bathurst | Bathurst |
| Quebec | 240043 | Consolidated Bathurst (Belgo) | Shawinigan |
| | 240042 | Consolidated Bathurst (Port Alfred) | La Baie |
| | 240046 | Donohue Inc. | Clermont |
| | 240048 | Industries James MacLaren (Masson) | Buckingham |
| | 240050 | La Compagnie de Papier QNS | Baie Comean |
| | 240047 | La Compagnie Gaspesia | Chandler |
| | 240049 | La Compagnie Price Ltee | Alma |
| | 240039 | Papeterie Reed Ltee (Daishona For.Prod.) | Quebec |
| | 240044 | Papier Journal Domtar | Dolbeau |
| | 240052 | Tembec Inc. | Temiscamingue |
| | | Abitibi Price | Beaupre |
| | | St. Raymond Paper Inc. | Desbiens |
| | | Abitibi Price (Kenogami) | Jonquiere |
| | | Canadian Pacific Fores Products | Trois Rivieres |
| | | Kruger Inc. | Trois Rivieres |
| Ontario | 351330 | Abitibi Paper Ltd. | Iroquois Falls |
| | 351338 | Abitibi Price (Ft. William) | Thunder Bay |
| | 351340 | Boise Cascade | Kenora |
| | 351318 | CIP Inc. | Hawkesbury |
| | 351065 | Ontario Paper Co. | Thorold |
| | 351326 | Spruce Falls P & P | Kapuskasing |
| | 351337 | Abitibi Price (Thunder Bay) | Thunder Bay |
| Manitoba | 460008 | Abitibi Price Inc. | Pine Falls |
| British Columbia | 590022 | Western Forest Products | Port Alice |

## References - Section A.27.2

Environment Canada, 1983a. "The Basic Technology of the Pulp and Paper Industry and its Environmental Protection Practices". Environmental Protection Programs Directorate, Training Manual EPS 6-EP-83-1.

Environment Canada, 1983b. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Prepared by Environmental Protection Programs Directorate, Report EPA 3-EP-83-10.

Johnson, N.D., 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emissions Inventory for Sources in Eastern Canada". Report prepared for Environment Canada by Ontario Research Foundation, Report P-5134/FG.

Lockwood -Post's Directory of the Pulp, Paper and Allied Trades, 1989. Miller Freeman Publications Inc., New York.

U.S. Environmental Protection Agency (U.S. EPA), 1986. "Compilation of Air Pollutant Emission Factors - AP-42, Supplement A", October.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory. Report prepared by Radian Corp., NTIS PB 87-1987-35.

## A.29.4 PRIMARY ALUMINUM PRODUCTION (SIC 29511)

### a) General Description

The production of aluminum is a two-step process. First, bauxite ore is ground, purified and calcined to produce alumina; then the alumina is electrically smelted. The first step is inventoried under SIC 29510, alumina production. The electrolytic reduction of alumina to aluminum is described in this section. The principal criteria pollutants of interest are particulate matter, $SO_x$ and CO.

### b) Sector Description

To produce aluminum, alumina is put through the Hall-Herout process, which is the electrolytic reduction of alumina dissolved in a molten salt bath of cryolite and various salt additives.

Aluminum reduction is carried out in shallow, rectangular cells (pots) made of carbon-lined steel with carbon blocks that are suspended above and extend down into the pot. The pots and carbon blocks serve as cathodes and anodes. The molten cryolite functions as both the electrolyte and the solvent for the alumina. Electrical resistance to the current passing between the electrodes generates heat that maintains cell operating temperature. Aluminum is deposited at the cathode, where it remains as molten metal below the surface of the cryolite bath. The carbon anodes are continuously depleted by the reaction of oxygen and anode carbon. The aluminum product is periodically tapped beneath the cryolite cover and fluxed to remove trace impurities. (U.S. EPA 1985)

There are three main types of reduction cells in use: prebake, horizontal stud Soderberg and vertical stud Soderberg. The prebake cell uses a replaceable, consumable carbon anode which is produced in a separate facility called the anode bake plant. Both Soderberg cells employ continuously formed consumable carbon anodes where the anode paste is baked by the energy of the reduction cell. (U.S. EPA 1985)

In the prebake cell process, anodes are produced as an ancillary operation, involving two main steps. The first step is paste preparation, which includes crushing, grinding and screening of coke and cleaned spent anodes (butts), and blending with a pitch binder in a steam jacketed mixer. In the second step, this green anode paste mixture is molded to form self-supporting green anode blocks. These blocks are baked in a direct fired ring furnace or an indirect fired tunnel kiln. The baked anodes, typically 14 to 24 per cell, are attached to metal rods and are expended as they are used. (U.S. EPA 1985)

The horizontal stud Soderberg process uses a "continuous" carbon anode. Green anode paste is periodically added at the top of the anode casing of the pot and is baked by the heat of the cell into a solid carbon mass, as the material moves down the casing. The cell casing is of aluminum or steel sheeting, permanent steel skirt and perforated steel channels, through which electrode connections (studs) are inserted horizontally into the anode paste. (U.S. EPA 1985)

The vertical stud Soderberg cell is similar to the HSS cell, except that the studs are mounted vertically in the anode paste. VSS cell construction prevents the installation of an integral gas collection device, and hooding is restricted to a canopy or skirt at the base of the cell where the hot anode enters the cell bath. (U.S. EPA 1985)

Emissions from aluminum reduction processes include particulate matter, carbon monoxide, volatile organics and sulfur dioxide from the reduction cells; and particulate matter, vaporized organics and sulfur dioxide from the anode baking furnaces. (U.S. EPA 1985)

A variety of control devices has been used to abate emissions from reduction cells and anode baking furnaces. To control gaseous and particulate fluorides and particulate emissions, one or more types of wet scrubbers (spray tower and chambers, quench towers, floating beds, packed beds, venturis) have been applied to all three types of reduction cells and to anode baking furnaces. Also, particulate control methods such as wet and dry electrostatic precipitators, multiple cyclones and dry alumina scrubbers (fluid bed, injected and coated filter types) are used with baking furnaces and on all three cell types. Also, the alumina adsorption systems are being used on all three cell types to control both gaseous and particulate fluorides by passing the pot off gases through the entering alumina feed, which adsorbs the fluorides. This technique has an overall control efficiency of 98 to 99 percent. Baghouses are then used to collect residual fluorides entrained in the alumina and recycle them to the reduction cells. Wet ESPs approach adsorption in particulate removal efficiency, but they must be coupled to a wet scrubber or coated baghouse to catch hydrogen fluoride. Scrubber systems also remove a portion of the $SO_2$ emissions. These emissions could be reduced by wet scrubbing or by reducing the quantity of sulfur in the anode coke and pitch, i.e., calcining the coke. (U.S. EPA 1985)

The following SCCs are used to inventory aluminum production:

| SCC | Description |
|---|---|
| 3-03-001-01 | Prebaked Reduction Cell |
| 3-03-001-02 | Horizontal Stud Soderberg Cell |
| 3-03-001-03 | Vertical Stud Soderberg Cell |
| 3-03-001-04 | Materials Handling |
| 3-03-001-05 | Anode Baking Furnace |
| 3-03-001-06 | Degassing |
| 3-03-001-07 | Roof Vents |
| 3-03-001-08 | Prebake: Fugitive Emissions |
| 3-03-001-09 | H.S.S.: Fugitive Emissions |
| 3-03-001-10 | V.S.S.: Fugitive Emissions |
| 3-03-001-11 | Anode Baking: Fugitive Emissions |

### c) Inventory Approach

Aluminum production facilities are inventoried as point sources of particulate matter, $SO_x$, $NO_x$, CO and VOCs. Wherever possible, site-specific emission factors and activity levels, based on tonnes of molten aluminum produced, should be used. Alternatively, literature emission factors specific to the type of process and emission control used at each facility should be used with site-specific production figures.

### d) Preferred Emission Estimation Procedure

The first step in the inventory is the preparation of a detailed list of the processes at each plant, along with information on the control equipment used on each process. A recent report by Environment Canada (1989) lists the processes and control equipment at all plants in Quebec. Details on the B.C. aluminum facility should be obtained by direct contact or through Environment Canada.

Environment Canada has site-specific emission factors for particulate matter, $SO_2$, $NO_2$, HC and CO (as appropriate) for materials handling, fugitive emissions, cell reduction and anode baking facilities. These are based on a combination of site-specific process, control and emissions information and literature emission factors from AP-42 (U.S. EPA 1985). All emission factors are given as weight of pollutant/tonne of product.

### c) Activity Level

Annual production rates may be determined for each process at each facility by direct contact with the company.

Alternatively, annual aluminum smelter capacity is available, on a plant basis, in the 1988 Canadian Minerals Yearbook (EMR 1988). Details are available in the report on percent of capacity at which each plant operated. This information can be combined with more detailed information in a report by Environment Canada (1988) to estimate annual production on a process basis.

The Canadian Minerals Handbook (EMR 1988) also discusses currently scheduled facility development plans.

### f) Alternate Emission Estimation Procedures

If site-specific emission factors are not available, literature-based emission factors may be used. The following sources are recommended:

| | | |
|---|---|---|
| particulate | - | detailed emission factors specific to control technology are available in AP-42 (U.S. EPA 1985) for everything except materials handling, which may be found in the 1985 NAPAP listing (U.S. EPA 1987). |
| $SO_x$ | -<br>- | uncontrolled emission factors may be calculated using formulae presented in AP-42.<br>the 1985 NAPAP listing provides uncontrolled emission rates by SCC. These are not based on AP-42. |
| $NO_x$ | - | limited factors are provided in the 1985 NAPAP listing - these do not agree with emission factors used by Environment Canada (e.g., Environment Canada 1983). |
| VOC | - | the 1985 NAPAP listing provides VOC emission factors by SCC. These are based on engineering judgement. These do not significantly differ from those used by Environment Canada. |
| CO | - | uncontrolled emission factors are presented in the 1985 NAPAP listing. Their basis is not given. |

These emission factors should be used to derive site and process-specific information for each facility, taking into account the process type and control equipment.

### g) Temporal Variability

No information pertaining to the temporal variability of emissions from aluminum production facilities was found.

## h) Geographical Variability

Aluminum production is inventoried on a point source basis.

## i) Point Source Establishment

The following aluminum production facilities were identified:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240010 | Alcan Smelters & Chemicals Ltd. | Jonquiére |
| | 240137 | " " | Alma |
| | 240138 | " " | Grande Baie |
| | 240012 | " " | Shawinigan |
| | 240013 | " " | Beauharnois |
| | 240014 | Canadian Reynolds Metals Co. Ltd. | Baie Comeau |
| | 240140 | Aluminerie du Bécancour Inc. (ABI) | Bécancour |
| British Columbia | 590003 | Alcan Smelters & Chemicals Ltd. | Kitimat |

## References - Section A.29.4

Energy Mines and Resources Canada (EMR), 1988. "The 1988 Canadian Minerals Yearbook".

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10.

Environment Canada, 1988. "Inventory of Polycyclic Aromatic Hydrocarbon Sources in Quebec". Prepared by Lavalin for Environment Canada. File 55526.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutants Emission Factors. Volume I: Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.29.5 COPPER AND NICKEL SMELTING (SIC 29590, 29592)

### a) General Description

A major portion of $SO_2$ emissions in Canada occur from smelting of copper and nickel ores, and control programs have been initiated in each province to reduce emissions from smelters within specific target dates. Pyrometallurgical operations, which may include successive stages of roasting, smelting and converting or other specialized furnace processes, are used to produce crude (unrefined) metals from sulphide concentrates. Particulate matter and metal oxide fumes are generated primarily by process operations such as roasting and converting. Relatively small amounts of $NO_x$ and HC are also emitted from fuel-burning operations. Various copper and nickel smelting processes have been described by U.S. EPA (1986) and Environment Canada (1987) with emphasis on air emissions.

### b) Process Description

Roasters (SCC 3-03-005-02 - Multiple Hearth):
(SCC 3-03-005-09 - Fluidized Bed):
(SCC 3-03-005-13 - Fugitive Emissions):

After grinding and flotation, ore concentrates (containing 25-35% sulphur) are mixed with flux and roasted in air in either a multiple hearth or fluidized bed chamber to produce calcines. Approximately 20 to 50% of the sulphur in the concentrates is eliminated as sulphur dioxide with higher concentrations in fluidized bed reactor gases (U.S. EPA 1986). In most instances, multiple hearth roaster gases containing particulate matter, sulphur dioxide (1.5 to 3% at copper smelters and 2 to 5% at nickel smelters), nitrogen oxides and small amounts of hydrocarbons are exhausted to electrostatic precipitators after combining with gases from other operations. On the other hand, fluidized bed roaster gases, (typically containing 10-12% $SO_2$ at copper smelters and 9 to 15% at nickel smelters) are usually controlled with a sulphuric acid plant. Small amounts of fugitive particulate and gaseous emissions occur at calcine discharge ports.

Smelting Furnaces (SCC 3-03-005-03 - Reverberatory Furnace):
(SCC 3-03-005-14 - Reverberatory Furnace Fugitive Emissions):
(SCC 3-03-005-07 - Reverberatory Furnace with Ore Charging-Without Roasting):
(SCC 3-03-005-10 - Electric Smelting Furnace):
(SCC 3-03-005-12 - Flash Smelting Furnace):

During smelting in reverberatory furnaces, either hot calcines from the roaster or raw concentrate is melted with flux to produce copper or nickel matte, which is tapped periodically after separation from slag. Heat is generated by partial oxidation of the sulphide charge with air or oxygen and from burning external fuel. Submerged carbon electrodes are used to treat the melt in electric furnaces. Higher sulphur dioxide concentrations are generated in flash smelting (10-70% $SO_2$) and electric furnaces (4-8% $SO_2$) than in the conventional reverberatory furnace (0.5-2% $SO_2$) and, in some instances, flash smelting furnace gases are controlled by a sulphur acid plant. Typical $SO_2$ off-gas concentrations in nickel smelting flash furnaces (10-50% before sulphur fixation) and in electric furnaces (0.5-2%) have been reported by Environment Canada (1987). Conventional reverberatory furnace gases are usually directed toward low velocity balloon flues and ESPs to remove particulate matter, but without $SO_2$ removal. Fugitive $SO_2$ emissions occur during slag skimming, matte tapping, and from furnace leaks.

Slag Cleaning Furnace (SCC 3-03-005-22 - Furnace):
(SCC 3-03-005-17 - Fugitive Emissions):

Slag from flash smelting furnaces, that contains residual copper, and converter slag, in some cases are heated in an electric slag cleaning furnace under reducing conditions in order to recover matte that settles for charging to converters. Both fugitive particulate and $SO_2$ emissions occur from this operation.

Noranda Reactor (SCC 3-03-005-28):

Copper matte is produced in a modified continuous process at one facility, whereby copper concentrates are smelted in a single vessel with heat supplied by oil burners and thermal energy from the concentrates. The reactor off gases, that may contain 5-15% $SO_2$, are presently controlled with a sulphuric acid plant.

Converters (SCC 3-03-005-04 - Converter Emissions):
(SCC 3-03-005-15 - Fugitive Emissions):

In the final conversion of matte to blister copper or high grade nickel matte, molten matte, flux and scrap metal are charged to refractory-lined, rotating converters in which air or oxygen-enriched air is blown into the sulphide melt for oxidation to the metal. Flue gases, containing 4-7% $SO_2$, in copper converters and 3.5 to 8% $SO_2$ in nickel converters, are captured during blowing by a hood over the converter mouth but fugitive emissions occur also during charging, blowing and pouring operations. Converter off gases are usually treated in ESPs for particulate removal or with sulphuric acid plants at some smelters to remove $SO_2$.

Anode Furnaces (SCC 3-03-005-16 - Fugitive Emissions):

Blister copper is further purified in a fire-refining anode furnace by sequentially oxidizing impurities (air blowing into the melt) and reducing metal oxides to the metal which is tapped and cast into anodes for electrolytic purification. Minor amounts of fugitive $SO_2$ and particulate matter are released during this process. The refining of blister copper and high grade nickel matte is done at separate refineries by various processes distinct from the smelting operation.

Fuel Combustion (SCC 3-03-900-01 to 03):

All of the common air pollutants are also emitted from use of fossil fuels in process heaters and other fuel combustion equipment.

### c) Inventory Approach

As primary copper and nickel smelters are major contributing sources of $SO_2$ emissions, point source methods should be used to prepare inventories. Similarly, direct source test data have generally been used for compiling emissions. Emission factors also have been used to estimate emissions associated with various processes where direct emissions data are lacking.

### d) Preferred Emission Estimation Procedure

In compiling smelter $SO_2$ emissions, it is recommended that detailed emissions data at the process level, where possible, be acquired directly from the producing companies and compared or verified with the best available means, such as material balances and published emission factors. Actual emissions from a particular unit will depend on the configuration of equipment in the smelter, the operating parameters and schedules, as well as ventilation arrangements and control device efficiencies. At most smelters, source sampling has been conducted at strategic emission locations and sulphur balances for each major process are routinely maintained. In order to approximate emissions or generally assess the validity of emission measurements, the following types of material balance and other information should be procured:

- individual process feed base quantities in accordance with the material flow patterns and facility operating schedules (e.g., continuous or intermittent operations),
- the sulphur and metal content of process feed materials (e.g., concentrates used with account of mixing ratios), specific process products (e.g., matte) and by-products (e.g., slag),
- the sulphur content and amounts of external process fuels used,
- pollution control device efficiencies (e.g., $SO_2$ removal by acid plant and/or $H_2SO_4$ produced).

It is recognized that specific uncertainties might occur in the sulphur mass balance approach, but such information may provide the best definition of overall emissions, and is also useful in determining sulphur losses in fugitive emissions. Despite the wide ranges of reported $SO_2$ off-gas concentrations for both copper and nickel smelting processes (U.S. EPA 1986, Environment Canada 1987), measured emission data will also guide or assist in material balance emission estimates. Hence, it is suggested that such balances be used in combination with actual source test data for a given facility, in order to derive direct fugitive and $SO_2$ emissions. Accordingly, source test data, that comprise combined emissions from several processes (i.e., depending on sampling locations) in conjunction with mass balances, should be used in preference to emission factor estimates for $SO_2$, as long as reliable test data were obtained under normal operating conditions. Similarly, direct source test data should be used, where possible, for other types of smelter emissions (e.g., particulate, $NO_x$, etc.). Where measurement data are lacking, emission factors, available for several smelter operations, should be used to estimate emissions for other on-site sources or specific pollutants such as particulate matter and $NO_x$. For example, emissions attributed to process fuels and fugitive dust should be accounted for in the total smelter emissions (see below).

### e) Activity Level

Smelter production data can be obtained from:

- provincial ministry files or point source listings,
- Industry, Science and Technology, Canada - Industry Profiles for Copper and Nickel (1988),
- annual reports for individual companies,
- plant rated annual capacity information for concentrates processed and metal produced (EM&R Reports 1989)
- the Canadian Mines Handbook (EM&R 1989, Canadian Mining Journal 1989).

However, it is recommended to contact individual plants in order to obtain relevant base quantity data (i.e., by process, where possible), the types and quantities of fossil fuels consumed, operating schedule data, specific control device information and any emissions data that may be available. At minimum, the amount of metal produced by the facility and metal concentrates processed should be procured. Preferably, all base quantity information, pertinent to a sulphur balance, should be obtained or examined from company records (e.g., material inputs, products and by-products for each operating stage). Fuel consumption data, incorporated with a given source, should be deducted from amounts of fuels compiled in the general industrial fuel combustion sector.

### f) Alternative Emission Estimation Procedures

Published or reported information that can be used to estimate emissions from smelters, based on emission factors, include:

- Environment Canada unpublished information,
- specific internal studies conducted by Environment Canada (Schultz International 1981 & 1982, Environment Canada 1987, ORF 1987, Environment Canada 1987).
- AP-42 emission factors (U.S. EPA 1986),
- NAPAP Inventory emission factors (U.S. EPA 1987).

Emission factors developed by Environment Canada, based on kg $SO_2$ emission per tonne of metal produced, are primarily determined for each facility from emission testwork or material balances as well as by back-calculating emission factors from reported emissions and base quantities. U.S. EPA uncontrolled emission factors for particulate and $SO_2$ emissions released by various process combinations are based upon amounts of copper concentrate processed. Data have been normalized to reflect that approximately 4 unit weights of concentrate are required to produce 1 unit weight of blister copper and that, in all but one process combination (i.e., reverberatory furnace followed by converters), emission factors were also normalized to 30% sulphur content in concentrated ore (U.S. EPA 1986). Typical control device efficiencies (e.g., particulate removal by ESPs and $SO_2$ removal by sulphuric acid plants) were also reported. Additional emission factors for $NO_x$, VOC and specific fugitive emission sources at copper smelters have been reported for the NAPAP inventory along with emission factors for fuels used in primary metal production process heaters. (U.S. EPA 1987). Fugitive particulate and $SO_2$ emission factors for nickel smelting operations have also been reported by Environment Canada (1987). Although generally similar, the emission factors derived by U.S.

EPA somewhat underestimate the $SO_2$ emissions reported for some Canadian smelters. Emission factors that have been back-calculated for various combined operations on a plant-specific basis have been reported elsewhere (ORF 1987).

Such back-calculated emission factors will provide only an emission estimate that might be useful for specific emission comparisons or updating emissions on an annual basis. With introduction of $SO_2$ emission controls, presently underway at some facilities, these emission factors will require significant revisions.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors require specific plant operating information, while continuous operation (i.e., uniform temporal factors) can be normally expected for most of the furnace processes in this industry.

### h) Geographical Variability

Actual smelter locations are available in Environment Canada files for spatially assigning emissions.

### i) Point Source Establishments

Canadian copper and nickel smelters are listed below and stack parameter information is available in files of the Inventory Management Division of Environment Canada.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240115 | Mines Gaspe | Murdochville |
| | 240016 | Mines Noranda Inc. | Noranda |
| Ontario | 351329 | Falconbridge | Falconbridge |
| | 351328 | Inco Metals Co. Ltd. | Sudbury |
| | 351327 | Kidd Creek Mines | Timmins |
| Manitoba | 460002 | Inco Metals Co. Ltd. | Thompson |
| | 46003 | Hudson Bay Mining & Smelting | Flin Flon |

## References - Section A.29.5

Energy, Mines and Resources Canada (EMR), 1989. "Canadian Minerals Yearbook, Mineral Report No. 37-Copper-W.McCutcheon, Nickel-R.G. Telewiak".

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# A.29.6 PRIMARY LEAD PRODUCTION (SIC 29990)

## a) General Description

Lead ore is crushed and concentrated, by extraction and flotation at the mine or mill site, to a fine sulphide concentrate containing 55 to 70% lead. Metallurgical processing of the concentrate at lead smelters involves three primary operations: sintering, reduction and refining. Sulphur dioxide and particulate matter are the major types of common pollutants emitted during the smelting processes.

## b) Process Description

Materials Handling (SCC 3-03-010-05):
Several generally minor sources of particulate emissions are associated with operations such as: ore crushing, raw materials unloading, transfer and storage. Dust control measures at lead concentrators during such operations are expected to be commonly employed. (See also Section A.09.1.)

Sintering (SCC 3-03-010-01 - Single Stream):
(SCC 3-03-010-06 - Dual Stream):
Lead sulphide is converted to lead oxide and lead sulphate during the sintering process, whereby concentrate, flux and recycled dross moving through the sintering machine on conveyors is blown with air (i.e., normally updraft windbox design) to form sinter by autogenous reactions at ~1000°C. Approximately 85% of the sulphur in the concentrate is eliminated by this process and the $SO_2$ produced in waste gases containing 1 to 8% $SO_2$, is treated in a contact sulphuric acid plant. In dual stream sintering operations, the weak $SO_2$ off-gases from the sinter box discharge are recirculated through the sinter bed in order to efficiently recover sulphur by the acid plant. Particulate emissions from sintering range from 5 to 20 percent of the concentrated ore feed. The most commonly employed particulate control devices are fabric filters and ESPs.

Blast Furnace (SCC 3-03-010-02):
Impure lead bullion is produced in a blast furnace in which the charge, comprising sinter, metallurgical coke and other slag-forming materials, is blown with combustion air. The combustion of coke provides the heat and carbon monoxide required to reduce the sinter to metallic lead. A low-grade $SO_2$ waste gas stream (0.8-2% $SO_2$) is emitted from the blast furnace primarily from residual sulphur in the sinter (i.e., a portion may remain bound to copper and other slag impurities) and most particulate emissions including lead oxide fume are removed by a control device (e.g., spray chamber and baghouse).

Slag Fuming (SCC 3-03-010-09):
Many of the impurities (e.g., arsenic, antimony, zinc, copper and other metal sulphides) are contained in the silicate slag layers that are continuously tapped from the blast furnaces. The slag may be processed at the smelter or shipped to other metal treatment facilities. Slag fume furnaces may be used to recover metal oxides from the tapped slag, and particulate emission controls such as fabric filters will normally be used.

Drossing Kettles and Dross Reverberatory Furnace (SCC 3-03-010-09 and SCC 3-03-010-03):
Lead bullion is further purified in drossing kettles (i.e., to remove copper and small amounts of sulphur and other impurities), refined by a series of physical/chemical processes to remove specific impurities from the melted bullion and finally cast for shipment. The dross, containing copper and other metallic impurities, is treated in a reverberatory furnace prior to shipment to copper smelters for metal recovery. Particulate matter is emitted from the reverberatory furnace which may be controlled by an ESP or baghouse. $NO_x$ emissions have also been reported for lead drossing, primarily from natural gas combustion. (U.S.EPA 1987)

Process Fuels (SCC 3-03-900-01 to 03):
Emissions of $SO_2$, $NO_x$ and HC will also be associated with fossil fuel combustion for process heating and other on-site boilers, etc.

## c) Inventory Approach

Primary lead smelters should be treated as point sources and methods to compile emissions may include use of source measurement data, material balances and reported emission factors, depending on the type of pollutant being considered.

## d) Preferred Emission Estimation Procedure

Information that can be used to estimate lead smelter emissions includes:

- Environment Canada unpublished information (Environment Canada, Schultz International 1981, ORF 1987),
- AP-42 emission factors (U.S. EPA 1986),
- NAPAP Inventory emission factors (U.S. EPA 1987).

It is recommended to contact individual lead-producing companies, in order to obtain emission measurement data for use in inventory compilations, as well as production data by process and mass balance information, to enable emission calculations to be made (i.e., to supplement emission measurement data). For example, available source test or continuous emission measurements (e.g., $SO_2$ or particulate measurements) at given site locations should be used for inventories, provided that data are reliable and representative of normal operating conditions. It is also suggested to estimate $SO_2$ emissions for given processes using sulphur mass balance information that should be available as part of plant production data. In order to compile emissions, the following types of plant information is recommended to be required:

- process feed base quantities (e.g., annual and incremental feed rates) and facility operating schedules (e.g., both continuous and batch operations),
- measured emission data at specified plant locations,
- the sulphur and lead content of process feed materials (e.g., lead concentrates, coke and other mixed feeds), specific process products

(e.g., sinter, impure lead bullion, etc.) and process by-products (e.g., slag, dross),

- process fuels consumed (e.g., type and quantity),
- estimated fugitive losses
- control device pollutant removal efficiencies (e.g., $SO_2$ removed by acid plant and $H_2SO_4$ produced, ESP or baghouse particulate removal efficiencies).

Process sulphur balances will assist in verifying measured $SO_2$ data and/or provide supplemental information regarding potential fugitive emissions (e.g., should significant differences be noted between measured and calculated $SO_2$ emissions). Information on the $SO_2$ concentration range that might be expected in blast furnace waste gas emissions has been reported by U.S. EPA. Similarly, typical amounts of sulphur that are captured/ retained by blast furnace slag are reported that requires incorporation into the material balance (U.S. EPA 1986). Process emission factors of other pollutants (e.g., particulate matter, HC) that may not have been extensively measured at lead smelters have also been reported (Environment Canada, U.S. EPA 1986 & 1987) and should be used in the absence of measured data. The type and removal efficiency of on-site control devices need to be determined from plant information in applying these emission factors. Similarly, fugitive particulate emission factors for several lead processing operations have been reported which should be used in estimating total plant emissions (U.S. EPA 1986 & 1987). Emissions related to process fuel combustion (e.g., $SO_2$, $NO_x$ and HC) can be estimated using published emission factors for primary metal industries (U.S. EPA 1987). The amount of fuel consumed should be deducted from amounts compiled for the general industrial fuel combustion sector (Section B.56.4).

### e) Activity Level

Lead production data can be obtained from the following published or other information:

- metal production by province (EM & R 1989, Canadian Mining Journal 1989),
- tonnes ore milled and metal content of concentrates produced by individual companies (Canadian Mining Journal 1989),
- annual reports of individual companies (e.g., Noranda),
- provincial agency internal files.

Depending on the type of process and applicable emission factor, base quantity data corresponding to amounts of raw ore and lead concentrate processed, lead sinter and lead metal produced are required. Where possible, such data should be procured from individual lead producers.

### f) Alternative Emission Estimation Procedures

Alternative emission estimates can be determined for the lead smelting industry, using published information where resources do not permit contacting individual companies. For example, emission factors have been reported at the process level for $SO_2$ and particulate emissions. Emission factors for $SO_2$ have been derived in previous Environment Canada emission inventories (Environment Canada internal files, ORF 1987), in some instances, from back-calculations of available plant emissions data with reported ore processing information by company (Canadian Mining Journal 1989, company annual reports). In using alternative estimating procedures, without acquiring plant-specific emissions data, uncertainties can be expected in the following areas:

- derived process level emissions,
- apportionment of calculated emissions data amongst individual producers,
- the magnitude of total emissions by plant, especially for particulate emissions with application of reported average control device efficiencies by process.

However, such alternative estimates (i.e., emission factor approach) are usually the only means available to deduce fugitive emissions. Related fuel combustion emissions (e.g., process heating) could alternatively be accounted for in the collective area source fuel combustion sector.

### g) Temporal Variability

The acquisition of average plant operating data in seasonal, daily and hourly increments (e.g., normal shift operating schedules) should be done in order to derive emission temporal factors at the process level or process emission-weighted temporal factors at the plant level. Production is normally constant throughout the year.

### h) Geographical Variability

By compiling emissions on a point source basis, the lead producer plant locations are known and are available within Environment Canada files.

### i) Point Source Establishments

The following lead smelters in Canada are reported in Environment Canada's point source listing (1990) and stack parameter information is also available in files of the Inventory Management Division of Environment Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| New Brunswick | 130001 | Brunswick Mining & Smelting Co. | Bathurst |
| British Columbia | 590028 | Cominco Ltd. | Trail |
| | 590004 | Cominco Ltd. | |

## References - Section A.29.6

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Environment Canada, Air Pollution Control Directorate, Pollution Data Analysis Division (unpublished information).

Environment Canada, Environmental Protection Programs Directorate, Industrial Programs Branch, Mining, Mineral and Metallurgical Processes Division (unpublished information).

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Report P-5134/FG prepared by Ontario Research Foundation for Inventory Management Division, Environment Canada.

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## A.29.7 ZINC PRODUCTION (SIC 29992)

### a) General Description

Zinc metal that is produced by the electrolytic process at Canadian smelters usually involves four major operations before zinc is cast: roasting, leaching, purification and electrolysis. Particulate matter and sulphur dioxide are the major types of common emissions associated with some operations at zinc smelters.

### b) Process Description

Raw Material Handling (SCC 3-03-030-09):
Zinc concentrates are usually crushed at the mine site (see Section A.09.1) and minor amounts of particulate emissions might be expected at the smelter while handling and transferring these materials.

Roasting (SCC 3-03-030-02 and 08):
Finely ground zinc sulphide concentrates (typically containing 49 to 54% Zn and 31% S) are oxidized to low sulphur calcine during the roasting process and emitted $SO_2$ is usually captured in an acid plant. A multiple hearth roaster is used at one Canadian zinc smelter, for which typical exhaust gases are reported to contain 4.5 to 6.5% $SO_2$ (U.S. EPA 1986). Fluidized bed roasters, used at other plants, are reported to release higher $SO_2$ concentrations in exhaust gases (i.e., 7 to 12% $SO_2$) which are controlled by direct contact sulphuric acid plants. Particulate emissions from roasters are controlled with cyclones followed by an ESP or scrubber before gases enter the acid plant.

Electrolytic Processing (SCC 3-03-030-06):
After leaching zinc oxide calcines with sulphuric acid and purifying the electrolyte by precipitating metallic impurities, zinc is deposited from solution onto cathodes in electrolysis cells. Acid mist is emitted in each of these operations.

Casting (SCC 3-03-030-11 and 15):
In the last stage, cathode zinc is melted and cast into slabs or ingots in which emissions of zinc fume can occur. Typically, particulate emissions from the melting furnace are controlled with impingers or by cyclones and baghouses.

Process Fuels (SCC 3-03-900-01 to 03):
$SO_2$, $NO_x$ and HC emissions can be expected to be associated with fuels combusted in process heaters and boilers.

## c) Inventory Approach

Point source methodology should be used to compile zinc smelter emissions. Direct source test data, material balance for sulphur and emission factors are methods most often used to inventory the associated particulate and sulphur dioxide emissions.

## d) Preferred Emission Estimation Procedure

Information sources that can be used to calculate particulate emissions for zinc smelters include:

- specific emission factors developed and reported by Environment Canada (Environment Canada 1983, Schultz International 1981 & 1982),
- AP-42 emission factors (U.S. EPA 1986),
- NAPAP Inventory emission factors (U.S. EPA 1987).

Direct contact with individual producers is recommended to procure available emissions and operating data. It is also recommended to conduct a sulphur material balance on roasting operations since this process represents the strongest $SO_2$ emission source at zinc smelters (i.e., or review available company-specific material balance data). The types of requested information should include as a minimum:

- available emission measurement data,
- process-specific production data in terms of zinc metal produced and concentrate processed (i.e., with the corresponding zinc and sulphur contents),
- operating schedule by type of process,
- the usage, type and removal efficiency for pollution control devices associated with pertinent operations (e.g., particulate removal efficiency by cyclones/ESP/baghouse, $SO_2$ removal efficiency and $H_2SO_4$ produced in acid plant controls),
- amounts and types of fuels consumed for processes and heating purposes.

Reported zinc and sulphur contents of typical roaster feeds and off-gases (U.S. EPA 1986) may be used as a guide in estimating uncontrolled $SO_2$ releases from roasters by a sulphur mass balance, but specific acid plant data will be required in determining amounts of $SO_2$ released in final emissions. A knowledge of the zinc content of materials may assist in verifying sulphur balance calculations, but may not be essential to the balance. However, representative measured emissions data, where available and considered reliable, should be used in preference to emission estimates by material balance or emission factors.

In most instances, reported emission factors may need to be used to estimate particulate emissions from zinc smelting operations and other emissions from fuel combustion used in processing or heating. Average uncontrolled and controlled particulate emission factors are reported for exhaust and fugitive emissions of various zinc smelting processes by U.S. EPA (1986) and other specific operations in another EPA report (1987). Plant-specific particulate control device efficiencies need to be applied in conjunction with these emission factors which are available in Environment Canada internal files. It should be noted that emission factors reported for the NAPAP study, in units of mass of pollutant per ton processed, relate to the unit amount of zinc slab produced (i.e., rather than concentrate processed). Emission factors of all common pollutants for various fuels used in process heaters at primary metal producers and boilers have been reported by EPA (1986 and 1987).

## e) Activity Level

Zinc production data can be obtained from:

- provincial ministry files based on information obtained in earlier inventories and internal studies,
- zinc metal produced by province and annual rated zinc capacity by plant (EMR 1989),
- annual reports of individual companies,
- ore milled and zinc content by company (Canadian Mining Journal 1989).

Where feasible, it is recommended to contact individual companies in order to obtain specific plant production data, the amount and zinc content of concentrate/other feed materials roasted and other operating data. Where fuel consumption information has been obtained through plant contact, amounts of fuels should be deducted from those compiled for general industrial fuel combustion (see Section B.56).

## f) Alternative Emission Estimation Procedure

Published data can be used to estimate zinc smelter emissions for various processes in instances where plant contact is not feasible. Average $SO_2$ and other emission factors have been determined in Environment Canada internal studies (Environment Canada, Schultz International 1981 and 1982, ORF 1987) and, in some cases, have been back-calculated on the basis of long-term emissions and base quantity information. Such emission factors might be used for updating or comparing plant-specific factors with other published factors but provide only an emission estimate. Average $SO_2$ and particulate emission factors for U.S. zinc smelting facilities have been reported (U.S. EPA 1986 and 1987) which can be used to supplement process emission estimates, where Canadian data are lacking. Control device efficiency data would need to be applied to the reported uncontrolled $SO_2$ emission factors for zinc roasters (U.S. EPA 1987). These emission factors in units of kg pollutant/tonne of Zn processed, can readily be applied to published zinc base quantities.

### g) Temporal Variability

Plant-specific operating data can be used in order to determine seasonal, daily and hourly temporal factors by process. Similarly, general operating information can be obtained from industrial associations to estimate plant-level temporal factors.

### h) Geographical Variability

Actual plant locations will be defined by compiling emissions on a point source basis.

### i) Point Source Establishments

Individual Canadian zinc smelter emission data and information regarding stack parameters is available in Environment Canada's Inventory System point source listing (1990) for the following plants:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240017 | Zinc Electrolytique du Canada Ltee | Valleyfield |
| Ontario | 351327 | Falconbridge Ltd. (Kidd Creek Mines) | Timmins |
| Manitoba | 460003 | Hudson Bay Mining & Smelting | Flin Flon |
| British Columbia | 590004 | Cominco Ltd. | Trail |

## References - Section A.29.7

Canadian Mining Journal, 1989. "Canadian Mineral Production", March.

Energy, Mines and Resources Canada (EMR), 1989. "Canadian Minerals Yearbook, Mineral Report No. 37 - Zinc - D. Audet".

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## A.29.9 FERROUS FOUNDRIES (SIC 2912? and 2941?)

### a) General Description

Ferrous foundries include facilities for the production of castings of various types of iron and steel, as well as alloys. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981).

Grey iron foundries (SIC 2941?) produce grey iron castings from scrap iron, pig iron and foundry returns by melting, alloying and molding. (U.S. EPA 1985)

Steel foundries (SIC 2912?) produce steel castings by melting, alloying and molding pig iron and steel scrap. (U.S. EPA 1981) Steel foundries that are part of an integrated iron and steel facility are not inventoried under SIC 2912?; they are inventoried as part of the integrated iron and steel facility under SIC 29192.

Particulate matter and CO are the main criteria pollutants emitted, although lesser amounts of $SO_x$, $NO_x$ and VOC are also emitted from certain process operations. (Environment Canada 1983, U.S. EPA 1985)

### b) Process Description

The major production steps of grey iron or steel foundries are raw materials handling and preparation, metal melting, mold and core production, and casting and finishing.

The raw materials handling operations include receiving, unloading, storing and conveying (using trucks, loaders and/or conveyors) of all raw materials for both furnace charging and mold and core preparation. Raw materials may be stored in open piles or enclosed storage areas. Raw materials are (U.S. EPA 1985):

|  | Grey Iron Foundries | Steel Foundries |
|---|---|---|
| metallic | pig iron<br>iron and steel scrap<br>foundry returns<br>metal turnings | pig iron<br>iron and steel scrap<br>foundry returns<br>metal turnings<br>alloys<br>carbon additives |
| fluxes | limestone<br>dolomite<br>fluorspar<br>calcium carbide | limestone<br>soda ash<br>fluorspar<br>calcium carbide |
| molding & casting | sand<br>sand additives<br>binders |  |
| fuels | coke, coal<br>oil and/or natural gas |  |

Melting of iron or steel metallic and flux charge is done in one of four main types of furnaces: cupola, induction, electric arc or reverberatory. In some cases scrap may be prepared prior to charge by solvent degreasing or heating. (U.S. EPA 1985, Environment Canada 1983)

Electric arc furnaces, the most common furnace used in steel foundries, are charged with raw materials by removing the lid, through a chute opening in the lid or through a door in the side. Molten metal is tapped by tilting and pouring through a hole in the side. Slag is removed through a slag door. (U.S. EPA 1985)

The cupola, the main type of furnace used in grey iron foundries, is the only furnace to burn coke as a fuel. The cupola is charged at the top with alternate layers of coke, metallics and fluxes. Iron is melted by the burning coke and the flux removes impurities in the iron to form slag. Both the molten iron and the slag are removed through tap holes at the bottom of the cupola. (U.S. EPA 1985)

Further details on all of these furnaces are provided in AP-42. (U.S. EPA 1985)

Molds, which are forms used to shape the casting exterior, are made of wet sand with clay and organic additives, dried with hot air. Cores, which are forms used to make the internal voids in castings, are made of sand with organic binders, molded into a core and baked in an oven. Used sand from castings shakeout operations is recycled to the sand preparation area where it is cleaned, screened and reused. (U.S. EPA 1985)

After the metal is tapped, usually into a ladle, it may be treated and is then poured into molds. When partially cooled, the castings are placed on a vibrating grid and the mold and core are shaken away from the casting. After the casting is completely cooled any burns, risers and gates are broken or ground off. The casting is then usually shot-blasted or tumbled to remove any remaining mold sand and scale. (U.S. EPA 1985)

Particulate matter is emitted from raw materials handling operations. These emissions may be controlled by enclosing major emission points and routing the air from the enclosures through fabric filters or wet collectors. (U.S. EPA 1985)

Scrap preparation with solvent degreasing results in the emission of hydrocarbons. Emissions from scrap preparation with heat include smoke, organics and carbon monoxide. Catalytic incinerators and afterburners can control about 95% of organic and CO emissions. (U.S. EPA 1985)

Emissions from melting furnaces include particulate matter, CO, VOCs, $SO_2$ and $NO_x$, although $SO_2$ emissions are characteristic of cupola furnaces and are attributable to sulfur in the coke. The highest concentrations of furnace emissions occur during charging, backcharging, alloying, oxygen lancing (in the case of steel), slag removal and tapping operations because furnace lids and doors are opened. If uncontrolled, emissions escape into the furnace building and are vented through roof vents. Emission controls for melting and refining usually involve venting the furnace gases and fumes directly to a control device. Fugitive furnace emissions control includes canopy or special hoods near the furnace doors and tapping hoods to route emissions to control systems. (U.S. EPA 1985) An environment Canada Survey (1983) found that, in Canada, a variety of control equipment was used in melting operations. For instance, scrubbers and wet caps were commonly installed on cupolas with afterburners for CO control, although cyclones, and sometimes baghouses, were also used. Collector units used on electric arc furnaces were baghouses and scrubbers (Environment Canada 1983). Emissions from induction and reverberatory furnaces were normally uncontrolled. (SNC/GECO Canada Limited and Ontario Research Foundation 1981)

The major pollutants from mold and core preparation are particulate matter, CO and VOCs. Baghouses and high energy scrubbers may be used to control particulate matter emissions. Afterburners and catalytic incinerators may be used to control VOCs and CO emissions.

Emissions from casting include particulate matter, CO and VOCs. Emissions from pouring are usually uncontrolled, although they may be vented. Emissions of particulate matter during shakeout are usually collected and controlled by either high energy scrubbers or bag filters.

Finishing operations result in the emission of particulate matter, which may be controlled by cyclone or baghouses.

There are two SCC classification systems for grey iron and steel foundries:

| SCC Type | SCC | Description |
|---|---|---|
| Area | 85100 | Ferrous Foundries - Induction Furnace (Hot-Melt) |
| | 85200 | Ferrous Foundries - Cupola Furnace (Hot Melt) |
| | 85300 | Ferrous Foundries - Electric Arc Furnace |
| Point | 3-04-003-XX | Grey Iron Foundry |
| | 3-04-007-XX | Steel Foundry |

Details of the subclassifications for the point source SCCs are available in the NAPAP 1985 point source emission factor listing. (U.S. EPA 1987)

## c) Inventory Approach

Ferrous foundries should be inventoried as point sources of particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides and VOCs. The preferred inventory method is to use site-specific emissions data, based upon some combination of permit data, source testing, process and control equipment characterizations, materials characterizations, materials consumption, production data and, if necessary, emission factors based on production rates or materials handled.

## d) Preferred Emission Estimation Procedure

The preferred emission estimation procedure is to use site-specific data to estimate emissions on a point-by-point basis. Direct contact with each operator is recommended to obtain the following information:

| | | |
|---|---|---|
| • | materials handling operations | main features, control methods and efficiencies, test data, permit data, metallic charge pretreatment methods ß(including amounts) |
| • | furnace | - type, emissions. collection methods, control equipment methods and efficiencies, test data, permit data, production data, schedules<br>- for cupola furnaces - coke characterization (sulphur content) and consumption rates |
| • | core and mold preparation | control methods and efficiencies, test data, permit data |
| • | metals treatment inoculation | control methods and efficiencies, test data permit data, amount of metal heated |
| • | pouring, cooling cleaning and finishing | control methods and efficiencies, test data permit data |

The data can be used to characterize emissions at each point of release within each operation. If site-specific emissions data, based on some combination of source testing and permit data is not available, the process, control and production data described above can be used to estimate emissions using emission factors from AP-42 (U.S. EPA 1985). These emission factors are based on production rates, with the exception of sand handling which is based on tons of materials handled. AP-42 provides emission factors for all processes in grey iron foundries and melting furnaces for steel foundries. Although no emission factors are available for non-furnace emission sources in steel foundries, AP-42 does indicate that they are very similar to those in iron foundries. Emission factors for uncontrolled emissions from the various foundry processes are listed in the 1985 NAPAP emission factor (U.S. EPA 1987) However, this listing is incomplete (e.g., particulate matter is missing) and the units are based on materials handling rates, rather than metal production or charge rates.

### e) Activity Level

In previous inventories (i.e., Environment Canada 1983), production estimates were developed from internally available questionnaire data. Since this information is dated, direct contact with the producer is recommended.

Statistics Canada produces an annual census on manufacturers (catalogue No. 41-250) and a monthly report on primary iron and steel industries, which includes SICs 29XX (catalogue No. 41-001). These can be used to draw up contact lists and apportion or confirm production data as required.

### f) Alternative Emission Estimation Procedures

Grey iron and steel foundries can be inventoried as area sources, using emission factors developed by Environment Canada (1983). These emission factors, which are based on tonnes of melt, were based on questionnaire data and represent an average emission rate, by furnace type, for the processes and control methods in use at the time (see also Environment Canada 1979).

## g) Temporal Variability

Hourly, daily and seasonal temporal factors for ferrous foundries are presented in a report by The MEP Company and Ontario Research Foundation (1985).

## h) Geographical Variability

Grey iron and steel foundries are preferably inventoried on a point source basis. Producer listings, with employee data, from Statistics Canada (41-001 and 41-250) can be used to geographically apportion emissions inventoried on an area source basis.

## i) Point Source Listings

Environment Canada does not currently inventory ferrous foundries as point sources.

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Environment Canada, 1979. "Air Pollution Emissions and Control Technology: Ferrous Foundry Industry". EPS 3-AP-78-1. Environment Canada, Ottawa.

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## A.29.10 FERROALLOY PRODUCTION (SIC 29110)

### a) General Description

Ferroalloy is the generic term for alloys of iron and one or more other metals, such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. These alloys are used mainly for deoxidation and alloying of steel. Alloys may be produced by one of four principal methods: blast furnace, electrolytic deposition, alumina silico-thermic process and electric arc furnaces. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981).

### b) Process Description

In Canada, the majority of ferroalloy is produced using submerged-arc open-top electric furnaces (EAFs) (Environment Canada 1983, SNC/GECO Canada Ltd and Ontario Research Foundation 1981, Ontario Research Foundation 1987). Only ferrosilicon, of various grades, and ferromanganese are produced in large quantities in Quebec.

In EAFs, raw ore, coke and slagging materials are smelted in a refractory-lined, cup-shaped steel shell by three submerged graphite electrodes. The intense heat zone around the carbon electrodes enables carbon reduction of the metallic oxides. The various impurities are trapped in the slag and molten ferroalloy is tapped from the bottom of the furnace and cast. A hood is usually located 1.8 to 2.4 m above the furnace crucible rim. Dust and fumes from the smelting processes are drawn into the hood and directed to a control device. (Environment Canada 1983, U.S. EPA 1985)

Particulate emissions from ferroalloy production occur during raw material handling, mix delivery, furnace operation and the crushing and sizing of solidified product. The major source of particulate emissions is the furnace itself. Particulate emissions also occur at furnace tap holes and during conveying, pouring and casting of the alloy. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981).

The smelting and tapping operations also result in the emission of $SO_x$ and CO (Environment Canada 1983). The 1985 NAPAP inventory also inventoried $NO_x$ (minor) and VOC emissions from EAFs producing ferrosilicon (various grades), silicon metal and silicon manganese (U.S. EPA 1987).

Dust emitted from raw materials handling, mix delivery and crushing and sizing of solidified product is collected by the cyclones, multicyclones and/or baghouses. The fine fume produced during furnace operations is more difficult to control and requires high efficiency collection such as fabric filters, electrostatic precipitators or high-energy venturi scrubbers. In Canada, smelters at major plants are controlled using baghouses or wet scrubbers. (Environment Canada 1983)

Emissions from ferroalloy production facilities may be inventoried using the following SCCs:

| | |
|---|---|
| 303003-11 | Primary Metals - Iron and Steel By-Product - Coke Coal Screening |
| 303003-99 | Primary Metals - Iron and Steel By-Product - Not Classified (i.e., Other Coke Handling) |
| 303006-01 | Primary Metals - Ferroalloy Open Furnace - 50% FeSi:EAF |
| 303006-02 | " " " " - 75% FeSi:EAF |
| 303006-03 | " " " " - 90% FeSi:EAF |
| 303006-04 | " " " " - Silicon Metal:EAF |
| 303006-05 | " " " " - Silicon Manganese:EAF |
| 303006-10 | " " " " - Ore Screening |
| 303006-11 | " " " " - Ore Dryer |
| 303006-13 | " " " " - Raw Materials Storage |
| 303006-14 | " " " " - Raw Materials Transfer |
| 303006-15 | " " " " - Ferromanganese:Blast Furnace |
| 303006-16 | " " " " - Ferrosilicon:Blast Furnace |
| 303006-17 | " " " " - Cast House |
| 303006-99 | " " " " " Other Not Classified |

SCC codes for semi-covered furnaces are also available under 303007-xx. (U.S. EPA 1987).

## c) Inventory Approach

The preferred emission estimation procedure is to inventory ferroalloy plants as point sources, using site-specific emission estimates of particulate matter, $SO_2$, CO and VOC verified using published process-specific emission factors or materials balance ($SO_x$).

## d) Preferred Emission Estimation Procedure

The first step in the inventory is the preparation of a detailed plant description, including the following types of information:

- plant facility descriptions, including all material handling, mixing, furnace, tapping casting and storage areas
- plant production data, including: the amount, types and characterization (i.e. S in coke) of feedstocks; annual production data for each type of ferroalloy and each furnace; slag characterization (i.e., S balance)
- emission control devices used and expected efficiencies for particulate matter, $SO_x$ and CO
- any reliable emission test data that can be made available
- any operating permits (i.e., certificates of approval) that specify current estimates of annual emissions or site-specific emission factors

Plant-specific emission factors and emissions data obtained directly from the operators can be supplemented and updated using emission factors available in the literature. Information sources that can also be used to calculate or verify emissions include:

- site-specific unpublished emission factors developed by Environment Canada based on survey data (Environment Canada 1983 and 1985) (particulate matter, $SO_2$, CO)
- site-specific unpublished emission rates/factors developed by the provincial environment ministry in Quebec (particulate matter, $SO_2$, CO)

- controlled and uncontrolled emissions factors reported in AP-42 (U.S. EPA 1985) (particulate matter, $SO_2$, CO and VOCs)
- summarized uncontrolled emission factors reported for the 1985 NAPAP inventory (U.S. EPA 1987) (particulate, $SO_x$, $NO_x$ and VOC)
- $SO_2$ (site-specific) emission factors developed by Environment Canada and the provincial environment ministry in Quebec (Ontario Research Foundation 1987)
- controlled and uncontrolled particulate matter emission factors specific to the products ferrosilicon (by grade) and ferromanganese developed by SNC/GECO Canada Ltd. and Ontario Research Foundation (1981)

### c) Activity Level

If production data are not available from the manufacturer, published production data can be obtained from:

- Statistics Canada produces a monthly report (41-001) on Primary Iron and Steel. This includes data on furnace charges, production and shipments of ferroalloys
- Canadian Minerals Yearbook (Energy, Mines and Resources, annual)

### f) Alternate Emission Estimation Procedures

Where less accurate data are required or where plant data is not available, emissions can be estimated using published emission factors (see Section d) and Canadian production data (see Section e). Total production data can be apportioned using data available in SNC/GECO Canada Ltd. and Ontario Research Foundation (1981).

### g) Temporal Variability

No temporal factors were identified for the ferroalloy production industry.

## h) Geographical Variability

The following ferroalloy producers are listed in the 1990 Residual Discharge Information System maintained by Environment Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240019 | Chromasco Ltee | Beauharnois |
| | 240102 | SKW Canada Inc. | Becancour |
| | 240144 | Elkem Metal Canada Ltd. | Beauharnois |
| | 240145 | Elkem Metal Canada Ltd. | Chicoutimi |

## References - Section A.29.10

Energy, Mines and Resources, annual. "Canadian Minerals Yearbook".

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Environment Canada, 1985. "Emissions and Trends of Common Air Contaminants in Canada (1970-1980)".

Ontario Research Foundation, 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Final Report P-5134/FG. Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, monthly. "Primary Iron and Steel". Catalogue No. 41-001.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". EPA-600/7-87-015. Prepared by Radian Corporation. U.S. Environmental Protection Agency, Washington, DC.

## A.29.11 IRON AND STEEL PRODUCTION (SIC 29192)

### a) General Description

This sector addresses large integrated steel companies that have smelting and refining capabilities to produce raw steel from iron ore with the use of blast furnaces and other converting processes. Companies that use steel scrap as the primary raw material, are classified as non-integrated mills (U.S. Bureau of Mines, 1985). After sintering and iron production, all contemporary steel making processes convert pig iron, scrap, direct-reduced iron or specific mixtures into molten steel by refining processes to reduce the carbon, silicon and oxygen content, as well as remove impurities such as phosphorus and sulphur. Steel mill products such as iron and steel castings, bars or rolls and specialty steels are produced by various semi-finishing or finishing operations with the complex. Most primary iron is produced in Canada with blast furnaces (12 in total) and direct reduced iron is produced at one facility in Quebec. Primary iron and titanium dioxide are also produced in electric furnaces at another non-integrated facility in Quebec (EMR 1989). Essentially, all of the common air pollutants are emitted from various processes, especially carbon monoxide and particulate matter, and extensive emission control is practiced by the steel industry, in order to comply with air pollution regulations. On a national basis, the emission contribution from integrated steel producers is significant, but not major, relative to other source sectors (Environment Canada 1990). It should be noted that coke production and associated emissions, although part of the primary steel making operations, are treated separately in this manual (see Section A.36.1).

### (b) Process Descriptions

<u>Sinter Production</u> (SCC 3-03-008-11 to 20):
The sintering process converts fine-sized raw materials (i.e., iron ore, coke breeze, limestone, mill scale and flue dust) with added water into an agglomerated sinter product for charging to blast furnaces (U.S. EPA

1986, Pechan 1990). Sintering is usually done at the steel-making complex, but is also done off-premises at one major facility in Ontario. The raw materials are loaded onto a continuous travelling grate (i.e., sinter strand) and are initially heated to ignite the coke, which provides sufficient heat (i.e., 1300 to 1480°C) to cause surface melting and agglomeration of the mix. A series of windboxes are located on the underside of the sinter strand that draw combustion air through the bed into a common duct leading to a gas cleaning device (e.g., cyclone followed by an ESP; wet scrubber or baghouse). The fused sinter is discharged at the end of the sinter machine, where it is crushed, screened and cooled in air or by water sprays. Hot crushing and screening operations are normally controlled by a baghouse or scrubber. After recrushing and screening the product is transferred for blast furnace charge (~2.5 tons of raw material is used to produce 1 ton of sinter). Most emissions, including particulate matter, $SO_X$, CO and hydrocarbons, occur at the sinter windbox, while particulate emissions also occur at the sinter discharge end and the cooler, with only minor amounts released in various other operations and material transfers. Apart from sinter cooling, emissions may be controlled by one or two common control devices.

Blast Furnace (SIC 3-03-008-1 and 2, and 3-03-008-21 to 27): Pig iron is produced in large, refractory-lined blast furnaces by the reduction of iron-bearing materials with coke under a high temperature and high velocity stream of air. The raw materials, charged continuously though the top, include natural iron ores or other iron-bearing agglomerated products (i.e., sinter or pellets), flux (i.e., limestone or dolomite) and coke. The iron oxides, coke and fluxes react with the countercurrent and preheated (~2000°F) blast air to form molten reduced iron, carbon monoxide and slag. The molten iron and slag which collect in the hearth at the base of the furnace are tapped and removed intermittently through runners. The high carbon pig iron is cast or transferred by ladle to steel-making processes and the slag is transported to a pit or remote dump, where is is granulated with water or allowed to solidify. The furnace base area, including iron and slag runners, is enclosed by a cast-house. The blast furnace top gas, containing dust and carbon monoxide, is cleaned in various stages by control devices such as cyclones, venturi scrubbers and ESPs for use as a fuel in checker stoves to preheat blast furnace air and in other plant operations.

Several potential emission points associated with the blast furnace operations might be expected. Often only small amounts of particulate emissions are normally released during top charging through gas seals, but occasional pressure releases due to 'slips' may occur. For example, pressure surges of gases and particulate matter result from cavities that form and collapse during charging and partial melting. The casting operation accounts for most of the primary emissions (i.e., particulate, $SO_x$, hydrocarbons), due to tapping and air contact with the molten materials. Cast-houses are usually controlled with hoods and evacuation systems that are vented to a baghouse or by suppression techniques that exclude air contact with molten surfaces.

Basic Oxygen Furnace (SCC 3-03-009-13 to 17):
The basic oxygen process produces low carbon steel from the charge of molten pig iron (~70%) and iron scrap (~30%) by injecting high purity oxygen to maintain exothermic conditions. The rotating, refractory-lined furnace (i.e., BOF) is commonly top-blown, whereby oxygen is lanced through the converter mouth or bottom blown, in which oxygen is introduced through bottom tuyeres. The released carbon monoxide may be either burned in the hood at the furnace mouth (i.e., open hood system) with combustion gases vented to a gas cleaning device, or ducted through a tight-fitting hood (i.e., closed hood system) to a wet scrubber before flaring at the scrubber outlet stack. After blowing, lime and florspar may be added to the vessel to achieve the desired slag characteristics, and the metal is poured into teeming ladles and subsequently poured into steel ingots.

The typical BOF cycle (~25 to 45 minute duration) comprises: scrap charging, hot metal charging, oxygen blowing/refining, temperature/ steel composition testing, alloying or re-blowing (where necessary), tapping and slagging. Particulate and CO emissions with smaller amounts of hydrocarbons may occur during any of the process steps, but most significant emissions are reported to be released during the oxygen blow period (U.S. EPA 1986). BOFs are equipped with primary hood capture systems over the furnace mouth to direct emissions to primary and/or secondary gas cleaning devices and all or a portion of the furnace may be enclosed or hooded with control devices to minimize emissions. BOF particulate emissions at Canadian facilities are typically controlled by electrostatic precipitators or venturi scrubbers (Environment Canada 1983).

Electric Arc Furnace (SCC 3-03-009-04 to 08):
Electric arc furnaces, used to produce carbon and alloy steels in batch at integrated steel plants and other ferrous foundries, are refractory-lined cylindrical pots in which graphite electrodes are inserted/retracted through the roof. The furnace is charged normally with 100% iron scrap by rotating the roof and, after melting, slag-forming materials are added and the furnace is back-charged with more metal or alloying materials through side doors. Oxygen is blown by lance for refining and the entire heat cycle ranges from 1 1/2 to 10 hours or more, depending on the product. Metal and slag tapping are done by tilting the furnace and pouring through side ports. Smaller induction furnaces may be used for various purposes in which the metal is heated by electric current induction, rather than electric arc. Emissions of particulate matter, CO and small amounts of the other common gaseous pollutants occur during charging/back-charging, oxygen lancing and tapping. Various combinations of emission ventilation systems are often used, such as: shell evacuation, side draft hood, combination hood, canopy hood and furnace enclosures (U.S. EPA 1986). The captured emissions are usually passed through an emission control device (e.g., fabric filter) (Environment Canada 1983, Pechan 1990).

Hot Forming and Semi-finishing (SCC 3-03-009-21 to 35):
After the molten steel is tapped or teemed from various furnaces, it is either continuously cast or poured into ingots which are subsequently heated and formed into shapes such as blooms, billets or slabs. In either case, scarfing is done by applying oxygen to the hot steel to remove surface defects before shaping or rolling. Machine scarfing particulate emissions may be controlled by an ESP or water spray. Either hot or cold rolling may be done and some form of heat treatment is usually applied in cold rolling to restore ductility of the sheet or strip.

Miscellaneous Combustion (1-02-007-04 and 1-04-007-7):
Steel plant operations require substantial amounts of heat or electrical energy. Combustion sources that are reported to produce emissions on plant property include: blast furnace stoves, boilers, soaking pits for steel ingots and reheat furnaces. Various types of conventional fossil fuels may be used but, where feasible, extensive use is made of blast furnace and coke oven gases. Emissions of $SO_2$, $NO_x$, CO, VOC and particulate matter (based on the dust content of the fuel) can be expected from the combustion of these fuels.

Open Dust Sources (SCC 3-03-008-31 to 34):
Fugitive and open dust sources such as vehicle travel on paved/unpaved roads, raw material handling and wind erosion from material storage piles/open terrain can also contribute significantly to coarse airborne particulate loadings in the vicinity of iron and steel plants. In addition to the amount and characteristics of the materials moved or disturbed, local meteorological factors will affect the fugitive dust emission rates.

## c) Inventory Approach

Inventories of iron and steel plant emissions are best compiled using point source methods, since all plants have been estimated to emit greater than 100 tonnes particulate matter and CO per year (Environment Canada 1990). Emission factors and/or direct source test data are most often used to estimate iron and steel facility emissions at the process level.

## d) Preferred Emission Estimation Procedure

Information sources that can be used to calculate process emissions for each of the pollutants include:

- specific unpublished emission factors and/or emission rates developed by Environment Canada (Environment Canada 1983, ORF 1987, SNC/ORF 1981),
- AP-42 uncontrolled and controlled particulate and CO emission factors (U.S. EPA 1986),
- uncontrolled emission factors for the common pollutants reported for the NAPAP emission inventory (U.S. EPA 1987),
- a summary of the available published emission factors for the iron and steel industry (Pechan 1990).

In order to compile accurate emissions and procure appropriate data, it is strongly recommended to directly contact the individual producers. Any relevant emission measurement data should be obtained that might be used in preference to published emission factors, as long as the data can be verified or adequately checked from process information. It is particularly important to acquire relevant control device information from the producers, where possible, since it might be expected that the various facilities utilize different types of control devices for given operations. Where source test or other specific data are lacking, it is recommended to use AP-42 emission factors for particulate and CO emission estimates, since information related to common control devices and efficiencies is reported. For $NO_x$, $SO_2$ and VOC, NAPAP emission factors have been consolidated and summarized and such factors are recommended, since these pollutants would essentially be expected to be uncontrolled. The emission factors are reported in kg/tonne of material processed or produced and/or other specific process activity. This requires particular attention to the appropriate units and acquisition of the applicable base quantity data. Estimated emission factors for fuels used and fugitive sources specific to the iron and steel industry are also available and discussed in AP-42. It is also recommended to conduct a material balance for sulphur oxide emissions associated with sintering operations for comparison with emission factor estimates. Accordingly, available data regarding the sulphur content and amounts of input/output materials used in the process will need to be consolidated, in order to derive the mass balance (e.g., iron ore, coke, flue dust and process fuels as well as the product sinter). This approach may be used in preference to emission factor estimates, especially in cases where material flows are variable.

### e) Activity Level

A rather limited amount of appropriate published base quantity data are available with regard to deriving accurate emission estimates for some of the complex processes within this industry. Some production data can be obtained from the following sources:

- Energy, Mines and Resources publications in the Canadian Minerals Yearbook, based on total Canadian crude steel production by process type and some individual producer capacities (see Primary Iron and Ferrous Scrap, Iron Ore) (EMR 1989),
- individual plant process equipment and specific capacities for some of the Canadian iron and steel producers (AISE 1989),
- the 1986 total Canadian steel shipments and provincial apportioning of the shipments (Science and Technology, Canada 1989).
- provincial statistics on the amount of coke oven gas used by the industry (Stats. Can. 1987),

However, where considered necessary, it is recommended to contact the individual steel-producing companies, in order to obtain relevant base quantity and operating data, process information pertinent to the identified emission sources, specific in-plant emission controls and any emissions data that may be available. For accurate emission assessments, the requested data should include as a minimum:

- the amount of iron produced in blast furnaces in conjunction with the type and amount of blast furnace feed (e.g., iron ore and/or agglomerate feed),
- the frequency of blast furnace slips per operating blast furnace unit (i.e., number per unit time interval),
- the amount of sinter produced on-site and/or the sulphur content and input/output material flows to the sintering process for determining sulphur oxide material balances,
- the amount of steel produced by individual or collective basic oxygen and electric arc furnaces,
- the usage, type and removal efficiencies for pollution control devices associated with pertinent operations,
- fuel types, sulphur content and consumption rates for fuels combusted in boilers, blast furnaces, soaking pits and reheat furnaces including fossil fuels and process-generated fuels,
- the number, type and distance travelled by on-site vehicles on paved and improved roads,
- the amount, type and characteristics of raw materials stored in open piles that may be subject to wind erosion,
- pertinent facility-specific emissions data that may substitute for emission factors.

It is recommended to include fuel consumption as a source of air pollutants at steel mills, since fuels such as blast furnace and coke oven gas are specific to this industry. In cases where conventional fossil fuel contributions are also included, the fuel totals (by fuel type) should be deducted from those compiled in the industrial fuel combustion area source sector (see Section B.56).

### f) Alternative Emission Estimation Procedures

In instances where less accurate emissions data are required than previously discussed, alternative emission estimates can be derived using published information. For example, production capacity data for some processes and known facility equipment, in conjunction with published economic indicators (e.g., relative annual iron ore and steel production in Canada), can be used with published emission factors to estimate emissions for the major types of sources at the existing iron and steel plants.

### g) Temporal Variability

Seasonal, daily and hourly temporal variations should be acquired from contact with the iron and steel industry, with respect to typical operating schedules of the various important processes.

### h) Geographical Variability

Locations of the major integrated and non-integrated iron and steel producers in Canada are known whereby emissions can readily be geographically apportioned (EMR 1979).

### i) Point Source Establishments

The following iron and steel plants are currently operating in Canada on the basis of information contained in Environment Canada point source listings and other information. Stack parameter data are also available in Environment Canada Inventory Management Division files.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Nova Scotia | 120001 | Sydney Steel Corporation | Sydney |
| Quebec | 240149 | QIT-Fer et Titane Inc.[1] | Tracy |
| | | Sidbec-Dosco Inc. | Contrecoeur |

| Province | Plant<br>ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351334 | Algoma Steel Corp. | Sault Ste. Marie |
| | 351332 | Algoma Ore Div.[2] | Wawa |
| | 351105 | Dofasco Inc. | Hamilton |
| | 351106 | Stelco | Hamilton |
| | 351074 | Stelco - Lake Erie Inc. | Nanticoke |

Notes

1. Non-Integrated Steel Producer
2. Sintering Process

## References - Section A.29.11

Association of Iron and Steel Engineers (AISE), 1989. "Directory - Iron and Steel Plants".

Energy, Mines and Resources, Canada (EMR), 1989. "Canadian Minerals Yearbook - Iron Ore.

Energy, Mines and Resources, Canada (EMR), 1989. "Canadian Minerals Yearbook - Primary Iron and Scrap".

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Prepared by Environmental Protection Programs Directorate, Report EPS 3-EP-83-20.

Environment Canada, 1990. "Canadian Emissions Inventory of Common Air Contaminants (1985)". Prepared by Inventory Management Division, Conservation and Protection, Report EPS 5/AP/3, March.

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emissions Inventory for Sources in Eastern Canada". Report prepared for Environment Canada, Report P-5134/FG.

Pechan (E.H.) and Associates, 1990. "Emission Factors for Iron and Steel Sources Criteria and Toxic Pollutants". Report prepared for the U.S. Environmental Protection Agency, NTIS PB 90-242314, June.

Science and Technology, Canada, 1989. "Industry Profiles - Primary Iron and Steel". Prepared by Regional Industrial Expansion, Ministry of State, Science and Technology.

SNC Geco Canada Inc. and Ontario Research Foundation (SNC/ORF), 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Report prepared for Environment Canada.

Statistics Canada, 1987. "Quarterly Report on Energy Supply-Demand". Publication No. 57-003.

U.S. Bureau of Mines, 1985. "Mineral Facts and Problems, 1985 Edition". U.S. Department of the Interior, Bureau of Mines Bulletin 675.

U.S. Environmental Protection Agency (U.S. EPA), 1986. "Compilation of Air Pollutant Emission Factors - AP-42 - Supplement A", October.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Report prepared by Radian Corp., NTIS PB87-1987-35.

## A.35.1 CONCRETE BATCHING (SIC 35510)

### a) General Description

Concrete is composed essentially of water, cement, sand (fine aggregate) and coarse aggregate (i.e., gravel, crushed stone or iron blast furnace slag). Concrete batching plants store, convey, measure and discharge these constituents into trucks for transport to a job site. Concrete mixing for the manufacturing of concrete pipe, concrete blocks, etc. is not considered in this sector. (U.S. EPA 1985)

Particulate matter is the only pollutant of concern for this sector.

### b) Process Description

Raw materials for a batch plant may be delivered by rail, truck or barge. The cement is transferred to elevated storage silos pneumatically or by bucket elevator. The sand and coarse aggregate are transferred to elevated bins using a front end loader, clam shell crane, belt conveyor, or bucket elevator. These constituents are then proportioned from the storage bins by means of weigh hoppers. (U.S. EPA 1985, SNC/GECO Canada Ltd. and Ontario Research Foundation 1981)

At most batch plants, the sand, coarse aggregate and cement are gravity fed from the weigh hopper into a transit-mix truck, where water is added. The batch product is transported, and mixed simultaneously, to construction sites for building purposes.

In central mix plants, the concrete is mixed at the plant and then delivered to the job site.

Most particulate matter emissions from these plants are fugitive in nature. Fugitive sources include the transfer of sand and aggregate, truck loading, mixer loading, vehicle traffic and wind erosion from sand and aggregate storage piles. Fugitive emissions control varies from plant to plant. Fugitive emissions, in Canada, are inventoried under SCC 55200.

The only controllable source, the transfer of cement to the silo, is usually vented to a fabric filter, or sock. This source is inventoried under SCC 55100.

The SCCs given above are for area sources. The following SCCs may be used to inventory concrete batch plants as point sources:

| | |
|---|---|
| 3-05-011-01 | General (non-fugitive) |
| 3-05-011-06 | Transfer Sand and Aggregate to Elevated Bins |
| 3-05-011-07 | Cement Unloading to Storage Bins |
| 3-05-011-08 | Weight Hopper Loading of Cement, Sand and Aggregate |
| 3-05-011-09 | Mixer Loading of Cement, Sand and Aggregate (Central Mix) |
| 3-05-011-10 | Loading of Transit Mix Truck |

### c) Inventory Approach

Concrete batch plants are inventoried as area sources of particulate matter. Emission factors based on the volume of cement produced are used in conjunction with assumptions about the typical amount of dust control, usually by province.

### d) Preferred Emission Estimation Procedure

Emission factors in the most recent version of AP-42 (U.S. EPA 1985) on concrete batch plants (Supplement A) may be grouped together to derive emission factors for SCC 55100 (equivalent to SCC 3-05-011-01) and SCC 55200 (the remaining operations listed under SCC 3-05-011 in section b) above). Assumptions must then be made on typical levels of control for these two area source types.

For SCC 55100, emission factors are for cement loading into the storage silo, controlled and uncontrolled.

For SCC 55200, fugitive emissions, emission factors in AP-42 (U.S. EPA 1985) are for typical operations.

In the 1978 inventory, Environment Canada (1983) assumed 60% emission control for Saskatchewan and 75% for the remainder of Canada. However, at that time, emissions of particulate matter were inventoried using a single emission factor and it is not clear as to how these control efficiencies relate to current practice and the newer emission factors.

### e) Activity Level

Statistics Canada publishes an annual report "Non-metallic Mineral Products Industries: Ready-Mix Concrete Industry". This may be used in conjunction with price indices (from?) to derive annual provincial production rates.

### f) Alternative Emission Estimation Procedures

Concrete batch plants could be inventoried as point sources, using site-specific annual production rates and source data, where available. The site-specific data could be supplemented as appropriate with emission factors from AP-42. Predictive equations which allow for emission factor adjustment based on plant-specific conditions are given in Section 11 of AP-42. (U.S. EPA 1985)

### g) Temporal Variability

Seasonal, daily and hourly temporal factors are available in a report by The MEP Company and Ontario Research Foundation (1981).

### h) Geographical Variability

Activity level data is available from Statistics Canada on a provincial basis. Further geographical apportionment could be based on building start information available from Statistics Canada and provincial housing ministries.

### i) Point Source Establishments

Environment Canada has one concrete batch plant listed in its Residual Discharge Inventory System:

| | |
|---|---|
| Plant ID: | 351109 |
| Plant Name: | Bay Concrete Product |
| Location: | Hamilton Ontario |

## References - Section A.35.1

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, annual. "Non-metallic Mineral Products Industries: Ready-Mix Concrete Industry".

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.35.2 GLASS MANUFACTURE (SIC 35620)

### a) General Description

The sector involves the manufacture of flat, container, pressed and blown glass products made from soda-lime glass, which is the majority of glass produced in Canada. Process emissions include particulate matter, $SO_X$, $NO_X$, VOCs and CO. Emissions associated with fuel combustion are inventoried separately as part of industrial fuel combustion (SIC 56223).

### b) Process Description

The procedures for manufacturing flat glass, container glass and pressed and blown glass are the same for all three types, except for the forming and finishing steps.

The major ingredients of soda-lime glass are sand, limestone, soda ash and cullet. As the sand, limestone and soda ash materials are received they are crushed and stored in separate elevated bins. These materials are then transferred through a gravity feed system to a weigher and mixer, where the material is mixed with cullet to ensure homogeneous melting. The mixture is conveyed to a batch storage bin where it is held until dropped into the feeder to the melting furnace. The main pollutant emitted by this batch plant, particulate matter, is usually controlled with 99 to 100 percent efficiency by enclosing dust sources and using baghouses or cloth filters, or by process modification such as briquetting or pelletizing. (U.S. EPA 1985, Supplement A)

The continuous regenerative furnace is the most commonly used melting furnace. As material enters the furnace through the feeder, it floats on the top of molten glass already in the furnace. As it melts, it passes to the front of the melter and eventually flows through a throat leading to the refiner, where it is heat-conditioned. After refining, the molten glass leaves the furnace and goes to be shaped by pressing, blowing, pressing and blowing, drawing, rolling, or floating to produce the desired product. The final step is annealing, with finishing as required (U.S. EPA 1985)

The melting furnace contributes over 99 percent of both particulate and gaseous pollutant emissions from a glass plant. In Canada, wet centrifugal scrubbers or baghouses are used to control particulate emissions (Environment Canada 1983). Emissions from forming and finishing operations vary depending upon the type of glass being manufactured, but are, in all cases, considered negligible. (U.S. EPA 1985)

The following SCCs are used to code the main processes involved in glass manufacture:

| | |
|---|---|
| 3-05-014-02 | Container Glass : Melting Furnace |
| 3-05-014-03 | Flat Glass : Melting Furnace |
| 3-05-014-04 | Pressed and Blown Glass : Melting Furnace |
| 3-05-014-06 | Container Glass : Forming and Finishing |
| 3-05-014-07 | Flat Glass : Forming and Finishing |
| 3-05-014-08 | Pressed and Blown Glass : Forming and Finishing |
| 3-05-014-10 | Raw Material Handling (all types of glass) |

### c) Inventory Approach

Glass manufacture plants are inventoried as point sources of particulate matter, sulfur oxides, nitrogen oxides, VOC and carbon monoxide. The preferred method of inventory is to use site-specific source information as specified in the provincial permit to operate. If this information is not available, average emission factors from AP-42 may be used in conjunction with process control and glass production information to estimate annual emissions.

### d) Preferred Emission Estimation Procedure

As stated above, site-specific emission rates based on source measurements and permit information are the preferred method of inventorying this sector.

If this information is not available, average emission factors and control device efficiencies for each process type and pollutant in AP-42, Supplement A (U.S. EPA 1985), may be used in conjunction with site-specific control data and production data. There is some indication in AP-42 that these emission factors may include fuel combustion (in the furnace) for this sector. If this is so, fuel use estimates should be subtracted from base quantities used in any industrial fuel combustion estimates.

### e) Activity Level

If emissions estimates are available from permit data, activity level data is not required. If the emission factor method is used, the preferred method of obtaining production data is through direct contact with the producers. Failing this, production can be estimated by using price indices (from?) and total Canadian production values from Statistics Canada (catalogue number 44-250B (3561) and assigning these to major producers.

### f) Alternative Emission Estimation Procedure

### g) Temporal Variability

No temporal factors were identified for glass manufacturing.

### h) Geographical Variability

Glass manufactures are inventoried as point sources.

## i) Point Source Establishments

The following plants are listed on the Residual Discharge Inventory System maintained by Environment Canada:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| New Brunswick | 130019 | Ahlstrom Canada Ltd. | |
| Quebec | 240095 | Consumers Glass Ltee. | Saint Pierre |
| | 240096 | Domglas Inc. | Montreal |
| Ontario | 351138 | Consumers Glass Co. | Toronto |
| | 351089 | Dominion Glass Co. Ltd. | Hamilton |
| | 351251 | Ford Glass Ltd. | Scarborough |
| | 351187 | Indusmin (Havelock) | Havelock |

## References - Section A.35.2

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Statistics Canada, 1988. "Non-metallic Mineral Products Industries. Primary Glass and Glass Containers Industry". Catalogue 44-250B 3561.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.35.3 ABRASIVES MANUFACTURE (SICs 35711 and 35712)

### a) General Description

Aluminum oxide with ferrosilicon by-product (SIC 35712) and silicon carbide (SIC 35711) are the two major synthetic abrasives manufactured in Canada.

Particulate matter, $SO_x$ and CO are the principal criteria pollutants emitted from the abrasives manufacturing processes.

### b) Process Description

The production of aluminum oxide involves smelting of bauxite ore with iron borings, petroleum coke and small quantities of various metal oxides in an electric arc furnace. The molten products (fused alumina and ferrosilicon) are cast into ingots for subsequent crushing.

Similarly, silicon carbide is produced in an electric-resistance furnace by charging a blend of silicon sand and petroleum coke or anthracite coal (?). The final product is then cooled and crushed.

Particulate matter emissions from synthetic abrasives manufacturing occur during raw materials handling and mixing, furnace operation and the crushing and sizing of the cooled product. However, most of the product is exported in bulk form to the United States, where it is crushed, screened and classified. Therefore, in Canada, furnace operations are the major source of particulate matter emissions, with materials preparation and handling being less significant. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981)

Unreacted carbon monoxide is emitted from the silicon carbide process and, to a lesser degree, in the production of aluminum oxide. (Environment Canada 1983)

Sulphur oxides are released from coke (or coal) during smelting (Ontario Research Foundation 1987), with the silicon carbide process releasing higher levels relative to the aluminum oxide process. Elemental sulphur may be added to the charge in aluminum oxide production, in order to increase product purity. (Environment Canada 1983)

A review of particulate matter emissions from raw materials handling and mixing found that these emissions, in Canada, are well controlled by mechanical cyclones and fabric filters. Major emissions from abrasives manufacturing were generated by furnace operation and, for silicon carbide production, were seemingly uncontrolled. Emissions from a majority (80%) of the furnaces producing aluminum oxide were controlled by baghouses with an estimated overall efficiency of 85%. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981)

No SCCs specific to abrasives manufacturing were identified.

### c) Inventory Approach

Abrasive manufacturing plants are inventoried as point sources of particulate matter, $SO_x$ and CO. The preferred inventory method is to use site-specific permit/operations data to develop emissions estimates.

Alternatively, emissions estimates can be estimated using emission factors based on production data.

### d) Preferred Emission Estimation Procedure

The preferred emission estimation method is to obtain specific emissions data by direct company contact, through the use of questionnaires or through permit or approvals data. Ideally, emissions data will be available for each facility, and will be based on some combination of source test data, material balances (for $SO_x$) and site-specific raw material characterizations, production data and control information.

If, however, site-specific emissions data are not available, then site-specific production could be used in conjunction with emission factors derived by Environment Canada (1983). These emission factors do not estimate emissions by the various steps in the process. Instead, emission factors are given by process and province, and reflect the typical production steps and process controls for each case. The emission factors, which are based on tonnes of product, were derived in the late 1970's and may not accurately reflect current production or control methods.

### e) Activity Level

The preferred method of obtaining production information is through direct contact, as described above.

Statistics Canada issues an annual report on the Abrasives Industry (catalogue no. 44-250B 3571). Production values are given by province. However, data is not available by product type. Commodity or price indices would be necessary to convert this information into annual production rates.

The Canadian Minerals Yearbook is another potential source of information, although reports on the abrasives industry are not always included.

Finally, federal and provincial ministries will have information available that can be combined to piece together information on major producers.

### f) Alternative Emission Estimation Procedure

The alternative activity level sources described in e) may be in conjunction with average emission factors derived by Environment Canada (1983) (see d) above).

### g) Temporal Variability

No temporal data for the abrasives industry was identified.

### h) Geographical Variability

In previous inventories (i.e., Environment Canada 1983) abrasives production has only been inventoried in Ontario and Quebec.

### i) Point Source Establishments

The following abrasive manufacturers are currently listed in the Residual Discharge Inventory System maintained by Environment Canada, under SIC 35711:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240023 | Compagnie Norton | Cap-de-la-Madeleine |
| | 240146 | Compagnie Norton | Shawinigan |
| Ontario | 351042 | ED Company (Canada) | London |
| | 351067 | General Abrasive Co. | Niagara Falls |

## References - Section A.35.3

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Ontario Research Foundation, 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, annual. "Non-Metallic Mineral Products Industries: Abrasives Industry". Catalogue No. 44-250B 3571.

## A.35.4 CEMENT PRODUCTION (SIC 35210)

### a) General Description

Hydraulic cement, of which Portland cement accounts for nearly all production, is used primarily for ready-mix concrete and is produced by either the dry or wet process. Dry process operations account for greater than 80% of Canadian cement production (EMR 1988). After preparing and blending raw materials, comprising mainly limestone, iron ore and shale or clay, the materials are calcined and fused in a rotary kiln to form clinker which is further treated and blended with gypsum to produce cement. In the process, between 45 and 65% of raw material weight is removed as carbon dioxide and water vapour (EPA 1986 and 1987) during conversion of calcium carbamate to lime and calcium silicates. Cement manufacture can result in significant amounts of both ducted and fugitive particulate emissions from several operations, as well as lesser amounts of $SO_2$ and $NO_x$ due mainly to process fuel combustion. Kiln exhaust represents the predominant source of particulate emissions, but substantial fugitive dust can occur if uncontrolled. Two source classification code (SCC) systems are used for inventory purposes with assignments to either the dry or wet process.

### b) Process Description

<u>Raw Materials Unloading, Transfer and Storage</u> (SCC 3-05-006-07, 08 and 12, or SCC 3-05-007-07, 08 and 12):
Raw materials are usually obtained from off-site quarries and are unloaded after transport to stockpiles or silos primarily by belt conveyors. Fugitive dust releases are associated with these operations and windblown dust losses can occur from storage piles of raw materials.

<u>Raw Material Crushing and Screening</u> (SCC 3-05-006-09, 10 and 11, or SCC 3-05-007-09, 10 and 11):
Limestone rock may be crushed and screened at the quarry or cement plant. If done at the cement plant, fugitive dust can occur at the primary and secondary crushers as well as screening and material transfer

stages. Otherwise, account should be made of these sources for quarry operations.

Raw Material Drying and Grinding (SCC 3-05-006-13):
The preparation of raw materials for dry kiln feed involves drying, proportioning, grinding and blending for suitable feed. Direct-contact rotary dryers, heated by kiln or clinker cooler exhaust gases (or sometimes directly-fired fuels), are used to reduce the crushed raw material moisture content to <1% either before or simultaneously during grinding. Dust from the raw materials being dried is entrained in the hot gases and conducted to a dust collector which may be in combination with the grinding system. Dry-process raw material grinding mills are usually operated in closed circuit and comprise several grind stages with air separators, in order to retain the fine portion. The kiln feed is normally mixed and blended during grinding. Dust collectors for the raw mill system are usually baghouses or sometimes cyclones, while fugitive dust emissions occurs during materials handling and transfer operations. In the wet process, a slurry is made by adding water to the initial grinding operation to result in a blended kiln feed slurry of 30-40% moisture or dewatered filter cake of about 20% moisture. Thus, dust emissions for these operations in the wet process should be minimal unless a portion of the grinding is done dry.

Dry and Wet Process Kilns (SCC 3-05-006-06 or SCC 3-05-007-06):
The pulverized (raw-meal or slurry) feed enters the upper end of the inclined cylindrical, rotary kiln which is refractory-lined and fired at the lower end by pulverized coal, oil or natural gas. During passage (1-4 hours), the raw materials re dried, calcined and fused to from clinker at temperatures in excess of 1400°C. In Canada, approximately 65% of the fossil fuel energy consumed by the cement industry is provided by coal, while natural gas provides about 32%. Kiln exhaust gases of the dry process are often used to preheat the feed prior to entering the kiln in a suspension preheater that results in considerably less energy consumption than achieved with the wet process. The process emissions originate from dust generated in the kiln (e.g., grinding and

tumbling action of materials within the kiln), as well as combustion-related gases such as $NO_x$ and small amounts of $SO_2$ and hydrocarbons. The cement industry generally uses electrostatic precipitators, mechanical collectors, fabric filter collectors, or combinations of these to control kiln particulate emissions. Multiclone and ESP control is most common. Dust collected by emissions control systems in various plant operations are partially injected into the kiln. Some units have an alkali bypass exhaust gas system (i.e., between the kiln and preheater), to avoid excessive alkali and sulphur buildup in the raw feed, and separate control devices collect particulate emissions from the bypass. Gaseous pollutant controls are not normally employed.

Clinker Cooler (SCC 3-05-006-14 and SCC 3-05-007-14):
Upon discharge from the kiln, the product passes through a clinker cooler, whereby quenching air passes either through or over a moving bed or stream of hot clinker. This reduces the clinker temperature and heat is recovered to preheat kiln or precalciner combustion air. Particulate emissions in off-gases from the grate coolers are ducted through a separate control device such as: settling chambers, cyclones, granular bed filters, ESP or baghouse.

Clinker Grinding (SCC 3-05-006-17, or SCC 3-05-007-17):
In the final stage of cement manufacture, clinker is ground with blended gypsum in a closed grinding system to obtain finished cement of fine particle size. The ducted particulate emissions from the finish mill circuit are usually retained by a fabric filter.

Other Fugitive Emissions:
Other sources of fugitive dust emissions include cement material handling, vehicular traffic on in-plant paved and unpaved roads, as well as wind erosion from roads and storage piles.

## c) Inventory Approach

In most instances, particulate emissions from Canadian cement manufacturing plants exceed 100 T/yr, and thus point source methodology should be used in inventories. Source test data are available for some Canadian cement plant kiln emissions, while reported controlled and uncontrolled emission factors, that are available for essentially all operations, should be used where necessary for estimating emissions based on individual plant production and in-place control devices.

## d) Preferred Emission Estimation Procedure

Documentation to estimate emissions rates can be obtained from:

- Environment Canada and other reports indicating measurements of particulate matter and other pollutants at specific facilities in Canada (Thorndyke 1984, 1985, 1986, 1987a and b),
- NAPAP uncontrolled emission factors (U.S. EPA 1987b),
- controlled and uncontrolled emission factors reported in AP-42 (U.S. EPA 1986).

It is recommended to acquire operating and emissions data directly from provincial, regional or industrial contact. Results from emission test measurements at a given facility should be used in preference to reported emission factors as long as data are representative of current operating conditions and can be verified from process information. More recent test data at specific Canadian facilities may also become available with which to update previous measurements. Otherwise, emission factors reported by U.S. EPA should be used to derive emission rates for each pertinent operation at a given plant. It is suggested to use controlled particulate emission factors published in AP-42 in accordance with the applicable type of control device by process at each plant (U.S. EPA 1986). However, it should be recognized that actual particulate emissions can vary significantly at the same facility, depending on the type of cement produced and other operating factors. Additional uncontrolled emission factors for specific fugitive particulate emission sources, published in a NAPAP report (e.g., raw material unloading and storage pile losses), should also be used to account for these sources (U.S. EPA 1987b). Attention should be given to the units of the emission factors (e.g., kg emission per tonne of raw material processed or cement produced).

Should control devices differ at a given plant from those of reported emission factors, then uncontrolled emission factors should be used along with typical particulate removal efficiencies for the given control device (U.S. EPA 1973).

Emission factors for nitrogen oxides and sulphur dioxide are also reported in AP-42. Nitrogen oxides can form in the kiln from the nitrogen content in both fuel and combustion air (i.e., thermal $NO_x$) at the high process temperatures. Similarly, $SO_2$ can be generated from the sulphur content of the fuels combusted and sulphur compounds in the ores. It can be expected that the sulphur content in these inputs will vary between facilities and at the same plant. However, a fraction of both of these acid gases can react with the alkaline cement (i.e., either within process chambers or when passing through particulate control devices upon contact with collected dust). It should be noted that the reported gaseous emission factors are for kilns operating without particulate control devices and that $SO_2$ reductions have been measured in a unit controlled by a baghouse (U.S. EPA 1986). Although the extent of $SO_2$ removal by cement plant particulate control devices is reported to be inconclusive (U.S. EPA 1986), others have stated that most of the $SO_2$ attributable to fuel sulphur is removed as it combines with alkaline materials (U.S. EPA 1987a). Test data, in conjunction with material balance and engineering estimates, at one cement plant in Ontario indicated that approximately 90% of the $SO_2$ emissions expected from fuel combustion was retained (Thorndyke 1985 and 1987). However, until additional data are available, it is recommended to use the gaseous uncontrolled emission factors reported in AP-42 that account for only partial $SO_2$ removal.

Accordingly, because of the probable $SO_2$/alkaline reactions, the amounts of fuel used for cement production (along with other specific industrial operations) should be deducted from general industrial fuel consumption (as noted in Section B.56.3), so that $SO_2$ emissions are not overestimated in the industrial fuel combustion sector. Similarly, because the emission factors for cement production include the combined process and fuel combustion emission contribution, fuels used by cement plants should be deducted from other industrial fuels, in order to avoid double-counting of emissions.

### e) Activity Level

Operating and other information pertaining to cement production should be acquired from provincial environmental agencies or directly from the cement producers. It is recommended to request data such as:

- the amounts of raw materials and cement produced,
- the extent of raw materials quarrying at the facility,
- the major types of process (e.g., wet/dry) for each operating kiln in conjunction with other auxiliary processing (e.g., preheater, precalciner, alkali control),
- the types and amounts of fuel used for kilns and driers including the sulphur content of the fuels,
- the types of in-place control devices for each process and removal efficiencies, where available, including procedures used to suppress fugitive dust emissions.

In compiling emissions, facility-specific test data or applicable emission factors should be used in conjunction with the amounts of raw materials processed or cement produced within the base year.

### f) Alternative Emission Estimation Procedures

Should base quantity data be lacking for a given facility, or should there be a need to verify data, individual cement plant clinker capacities in

Canada, along with the plant descriptions, have been reported by Energy, Mines and Resources (EMR 1988). For estimating emissions, total annual cement production by province is also included in this publication and the Canadian Mining Journal, such that individual plant production can be estimated by prorating annual production figures with plant capacities in each province. These data can then be used to derive approximate emissions.

### g) Temporal Variability

Cement plant operating information (e.g., through contact with facilities or the Portland Cement Association) should be used to derive seasonal, daily and hourly emission temporal factors. Normally, it can be expected that kiln operations are continuous, except for inadvertent malfunctions or other upsets.

### h) Geographic Variability

Cement plant locations are known and, thus, emissions can be readily geographically apportioned.

### i) Point Source Establishments

Cement plants operating in Canada are listed below, based on Environment Canada point source listings and EMR publications. Stack parameter data are contained in Environment Canada Inventory Management Division files.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Newfoundland | 100010 | North Star Cement Ltd. | Cornerbrook |
| Nova Scotia | 120018 | Lafarge Canada Inc. | Brookfield |
| New Brunswick | 130017 | Lafarge Canada Inc. | Havelock |
| Quebec | 240085 | Ciment Québec Inc. | St. Basile |
| | 240087 | Lafarge Canada Inc. | Montreal |
| | 240088 | Lafarge Canada Inc. | St. Constant |
| | 240141 | St. Lawrence Cement Inc. | Joliette |
| | 240142 | St. Lawrence Cement Inc. | Beauport |

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351002 | Lafarge Canada Inc. | Woodstock |
| | 351287 | Lafarge Canada Inc. | Bath |
| | ? | Federated White Cement Ltd. | Woodstock |
| | 351320 | St. Mary's Cement Co. | St. Mary's |
| | 351257 | St. Mary's Cement Co. | Bowmanville |
| | ? | St. Lawrence Cement Inc. | Mississauga |
| | 351301 | Lake Ontario Cement Ltd. | Picton |
| Manitoba | 460021 | Inland Cement Ltd. (CBR) | Winnipeg |
| | ? | Lafarge Canada Inc. | Fort Whyte |
| Saskatchewan | 470034 | Inland Cement Ltd. (CBR) | Regina |
| Alberta | 480117 | Lafarge Canada Inc. | Exshaw |
| | 480154 | Inland Cement Ltd. (CBR) | Edmonton |
| British Columbia | 590054? | Lafarge Canada Inc. | Kamloops |
| | ? | Lafarge Canada Inc. | Richmond |
| | ? | Tilbury Cement Ltd. (CBR) | Tilbury Island |

## References - Section A.35.4

Canadian Mining Journal, 1988. Canadian Mineral Production, March.

Energy, Mines and Resources (EMR), 1988. Canadian Minerals Yearbook.

Thorndyke, S.J., 1984. "Environmental Testing During Liquid Industrial Waste Burning in a Rotary Cement Kiln for Canada Cement Lafarge Ltd. Plant No. 4 Woodstock, Ontario" Ontario Research Foundation Report No. P-4391/I, for Canada Cement Lafarge.

Thorndyke, S.J., 1987b. "Preliminary Assessment of Air Emissions for the St. Lawrence Cement RDF Study". Ontario Research Foundation Report 46-30498 for St. Lawrence Cement Ltd., January.

U.S. Environmental Protection Agency (U.S. EPA), 1973. "Air Pollution Engineering Manual, 2nd Edition - AP-40". Report prepared by Office of Air Quality Planning and Standards (J.A. Danielson, Ed.), May.

U.S. Environmental Protection Agency (U.S. EPA), 1986. "Compilation of Air Pollutant Emission Factors - AP-42, Supplement A".

U.S. Environmental Protection Agency (U.S. EPA), 1987a. "Line and Cement Industry Particulate Emissions Source Category Report. Volume 2. Cement Industry". Midwest Research Institute. Report prepared for U.S. Environmental Protection Agency, NTIS PB 87-168654, February.

U.S. Environmental Protection Agency (U.S. EPA), 1987b. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Report prepared by Radian Corp. NTIS PB87-198735.

## A.35.5 GYPSUM PROCESSING (SIC 35930)

### a) General Description

In the processing of mined gypsum after crushing and drying, a calcium sulphate hemihydrate is obtained by calcining which is used most extensively for wallboard in building construction (EMR 1989, U.S. EPA 1983). Smaller amounts of crude gypsum, that has been crushed and dried only, are used as portland cement setting inhibitors, agricultural fillers and other end uses. Dust is the major common pollutant released during processing of gypsum and the calcining operation usually represents the largest plant source (SNC/ORF 1981). On the basis of previous inventory data, most plant emissions exceed 100 tonnes/yr of particulate matter. Gypsum mining emissions, where on-site mining occurs at some Canadian facilities, are addressed elsewhere in this manual (i.e., Mining and Rock Quarrying Sectors).

### b) Process Description

Raw Material Crushing and Handling (SCC 3-05-015-02 to 09):
Generally small amounts of particulate matter are emitted during gypsum ore size reduction operations such as: primary and secondary crushing/grinding, screening and conveying ores and/or other aggregates. These fugitive emissions may be controlled by mechanical collectors such as cyclones (Formica 1976).

Gypsum Dryer (SCC 3-05-015-01):
Fuel-fired rotary dryers are used to remove free water from the gypsum ore, where necessary. Some particulate carryover might be expected and emissions of $SO_2$, $NO_x$ and VOC are anticipated due to fuel combustion during drying. In some cases, drying and crushing are accomplished simultaneously in a heated rolling mill which eliminates the need for a rotary dryer. Cyclones and sometimes fabric filters are used to both collect the product and control emissions (Formica 1976).

Calcining (SCC 3-05-015-11 to 13):
The finely milled and dried gypsum ore is then calcined by one of three processes, at temperatures ranging from 120 to 205°C to form $CaSO_4 \cdot 1/2\ H_2O$ that is commonly known as plaster of paris or stucco. Kettle calciners may be used whereby the gypsum is indirectly heated. in batch or continuous mode, by hot gases passing through flues and the product is discharged into a hot pit. Alternatively, flash calciners are used in which combustion gases are directly contacted with the powdered gypsum in the base of the kettle. Natural gas is often used as the primary fuel. At some gypsum plants, processing is done by heated impact mills in which hot gas contacts the gypsum while grinding to essentially eliminate the need for rotary dryers, calciners and roller mills. Emissions of particulate matter with combustion gases occur during calcining and, in most cases, fabric filters or ESPs are used for particulate emission control. New plants operate almost exclusively with fabric filters (SNC/ORF 1981).

Conveying/Mixing (SCC 3-05-015-18):
Small amounts of fugitive dust may occur while transferring ore and stucco between processes, with screw or bucket conveyors, and mixing with other dry aggregates or additives.

Board End Sawing (SCC 3-05-015-21 or 22):
In wallboard manufacturing plants, a slurry of stucco and additives is moulded between paper rolls which hardens along the conveying line. The board is rough cut and dried in a multideck kiln dryer prior to trimming ends of the rigid board. Particulate emissions occur primarily during board end sawing.

## c) Inventory Approach

Emissions attributable to gypsum processing should be compiled using point source methodology and, where possible, information to estimate emissions should be procured directly from the individual producers. It is anticipated that rather limited recent Canadian source test data will be available regarding gypsum processing emissions and, if so, inventory estimates will need to rely on published emission factors for various processes.

### d) Preferred Emission Estimation Procedure

The primary sources of information that are available to calculate gypsum processing emissions include:

- controlled and uncontrolled particulate emission factors by process reported in AP-42 (U.S. EPA 1983),
- uncontrolled particulate and other gaseous emission factors by process reported for the 1985 NAPAP inventory (U.S. EPA 1987).

It is recommended to contact individual plants or provincial government agencies in order to request facility-specific operating data (see below), control devices used with particulate removal efficiencies and any source test data for a given process that may be available. Representative measurement data should be used to define emissions, where possible, or reported emission factors should be applied. It is suggested that gaseous emissions (e.g., $SO_2$, $NO_x$ and VOC), that are known to be attributable to fuel combustion during gypsum processing be assigned to the industrial fuel combustion sector (Section B.56.3). Alternatively, if fuel combustion emissions are included for each plant based on NAPAP emission factors, the amounts of fuel used for operations such as dryers and calciners at gypsum plants should be deducted from the total amounts of industrial fuels. For particulate emission estimates, it is recommended to use emission factors reported in AP-42, in conjunction with the types of processing operations and control devices employed at each plant. In stances where control devices other than fabric filters or ESPs are used, the uncontrolled particulate emission factors should be applied with account of the removal efficiency for the given type of control device. Typical dust removal efficiencies by various types of control devices are also reported in AP-42. It should be noted that the units of the published emission factors are based on process output production rates (e.g., kg/tonne dry ore, kg/tonne calcined gypsum, kg/$m^2$ of wallboard) rather than consistently related to amounts of gypsum processed.

### e) Activity Level

Rather limited published base quantity information exists for the gypsum processing industry. The annual amounts of gypsum produced in each province is reported in the Canadian Mining Journal (CMJ 1989) and shipments of crude gypsum by province is reported in the Canadian Minerals Yearbook (EMR 1989). However, these data include the provincial amounts of gypsum mined rather than products or amounts processed and processing does not necessarily occur in some provinces with gypsum mines. Similarly, very little production data for individual plants are published in these documents. Individual mining and processing plant capacities are available in an earlier Canadian publication (EMR 1977). For an accurate emissions assessment, it is recommended to contact provincial government agencies, mining associations or individual producers, in order to acquire base quantity data. Along with processing emissions data and control device information, examples of the types of requested information should include:

- annual amounts of crude and/or calcined gypsum processed at the facility, as well as amounts of product gypsum (e.g., number or area of wallboards by size, amounts of bulk products, etc.),
- the types of processes used at the facility (e.g., separate dryers and calciners, combined processing with heated impact mills, etc.),
- production operating schedules.

After procuring base quantity data by process type, along with types of emission controls used, particulate emissions can be estimated with published emission factors or available source-specific measured data.

### f) Alternative Emission Estimation Procedure

Essentially, no alternative approaches to the emission factor method have been identified for estimating emissions resulting from gypsum processing. It can be assumed that few changes to plants in the industry have occurred in recent years, apart from replacing multi-stage drying/crushing operations to heated impact mills at specific plants. In the event that base quantity data are not readily available, estimates may be derived for each operating plant by prorating provincial amounts of gypsum produced with individual plant capacities (EMR 1977).

### g) Temporal Variability

The quantities of gypsum produces processed in Canada might be expected to vary between seasons with dependence on building construction requirements. It is recommended to obtain plant-specific operating data in order to to derive emission temporal profiles or utilize published quarterly construction statistics (e.g., housing starts reported by Statistics Canada) as a surrogate indicator of seasonal temporal factors. Typical daily and hourly production information should also be acquired from specific producers in the industry.

### h) Geographical Variability

Fractions of gypsum processing facilities are known, whereby emissions can readily be geographically apportioned.

### i) Point Source Establishments

Based on information contained in Environment Canada Inventory Management files and published in the Canadian Minerals Yearbook (EMR 1989), the following gypsum processing facilities are operating:

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Newfoundland | 100011 | Atlantic Gypsum Ltd. | Cornerbrook |
| Nova Scotia | ? | Domtar Inc. | Windsor |
| Quebec | ? | CGC Inc. | Montreal |
|  | ? | CGC Inc. | St.-Jerome |
|  | ? | Westroc Industries Ltd. | Ste. Catherine d'Alexandrie |
| Ontario | ? | CGC Inc. | Hagersville |
|  | 351052 | Domtar Inc. | Caledonia |
|  | ? | Westroc Industries Ltd. | Clarkson |
| Manitoba | 460019 | Domtar Inc. | Winnipeg |
|  | 460022 | Westroc Industries Ltd. | Winnipeg |
| Alberta | ? | Domtar Inc. | Calgary |
|  | ? | Domtar Inc. | Edmonton |
|  | 480120 | Westroc Industries Ltd. | Calgary |
| British Columbia | ? | Domtar Inc. | Vancouver |

## References - Section A.35.5

Canadian Mining Journal (CMJ) 1989. "Canadian Mineral Production 1988".

Energy, Mines and Resources Canada (EMR 1977). "Operators List 1. Metal and Industrial Mineral Mines and Processing Plants in Canada".

Energy, Mines and Resources Canada (EMR 1989). "Canadian Minerals Yearbook - 1989".

Formica, P.N. (1976). "Controlled and Uncontrolled Emission Rates and Applicable Limitations for Eighty Processes". NTIS PB-266 378, September.

SNC/GECO and Ontario Research Foundation (SNC/ORF), 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Unpublished report prepared for Pollutant Data Analysis Division, Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1983. "Compilation of Air Pollutant Emission Factors - AP-42". 3rd Edition, May.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory", EPA/600/7-87-015.

# A.35.6 LIME MANUFACTURE (SIC 35810)

## a) General Description

Lime is produced by calcining limestone at high temperatures. The basic process steps are:

- quarrying raw limestone
- crushing and sizing limestone
- calcining limestone in kilns
- hydrating lime (not all lime is hydrated)
- miscellaneous transfer, storage and handling operations

Inventory methods for limestone and other rock quarrying are discussed separately in Section A.08.1. The remaining process steps are discussed in this section and inventoried under SIC 35810.

Particulate matter is the only pollutant of concern from most of the operations. Kilns also emit gaseous pollutants, principally $SO_x$. Relative to several other source sectors, inventory data indicate that lime manufacturing operations are not a major source of particulate emissions in Canada.

## b) Process Description

Raw Materials Unloading, Transfer and Storage (SCCs 3-05-016-07, 08 and 10):
Limestone, usually obtained from off-site quarries, is unloaded after transport to stockpiles or silos primarily by belt conveyors. Fugitive dust releases are associated with these operations and windblown dust losses can occur from storage piles.

Raw Material Crushing and Screening (SCCs 3-05-016-01 and 02):
Limestone rock may be crushed and screened at the quarry or at the lime plant. If done at the lime plant, fugitive dust can be released at primary and secondary crushing, as well as screening and material transfer

stages. If these operations occur at the quarry, fugitive dust emissions should be accounted for as part of quarry operations.

Kilns (SCCs 3-05-016-03, 04, 05 and 06):
Calcination of sized limestone is accomplished in kilns by burning at sufficiently high temperatures to dissociate and release carbon dioxide from the carbonate rock. The product quicklime can be altered by additional processing to form either slaked or hydrated lime.

Although several kiln designs are available, rotary and vertical kilns are used most frequently in Canada. Some calcimatic process kilns are also used. (SNC/ORF 1981)

In the rotary kiln, a long, cylindrical, slightly inclined, refractory-lined furnace, the limestone and hot combustion gases pass counter-currently. Rotary kilns may be fused with coal, oil or natural gas. (U.S. EPA 1985)

The vertical kiln is an upright, heavy steel cylinder lined with refractory material. The limestone is charged at the top of the kiln and is calcined as it slowly passes through to the bottom of the kiln. Vertical kilns cannot usually be fired with coal, due to problems with product quality. (U.S. EPA 1985)

Other less common kiln types are the calcimatic and fluidized bed kilns. The calcimatic kiln is a circular shaped kiln with a slowly revolving hearth. In fluidized bed kilns, fine grade limestone is mixed with hot combustion air usually above a perforated grate. These kilns may not be fired with coal. (U.S. EPA 1985)

Of these kiln types, fluidized beds have the highest uncontrolled particulate matter emissions due to the combination of small feed size and high air flow through the kiln. The rotary kiln is second in uncontrolled particulate emissions caused by small feed size, relatively high air velocities and dust entrainment. Calcimatic kilns release somewhat less particulate matter emissions, largely due to larger feed size. The vertical kiln has the lowest emission rates because of large lump feed, lower air velocities and slow movement of the limestone through the kiln. (U.S. EPA 1985)

Particulate emission control devices are used on most kilns in Canada. Larger particles are typically controlled with fallout chambers or cyclones. However, most kilns are equipped with fine particulate control devices such as: fabric and gravel bed filters, wet scrubbers or electrostatic precipitators. (U.S. EPA 1985)

$SO_x$ is the primary gaseous pollutant emitted from the kiln, resulting mainly from the combustion fuel. Not all of the sulphur in the kiln fuel is emitted unless no particulate emission controls are used or emissions are controlled only with mechanical collectors. Where secondary particulate controls are used (e.g., scrubber, ESP, baghouse), a major fraction of the emitted $SO_2$ is reported to be retained, presumably by reaction with collected alkali materials. Nitrogen oxides and carbon monoxide are reported to be emitted from the kilns in negligible amounts. (U.S. EPA 1985)

Product Cooler (SCC 3-05-016-11):
Product coolers are only particulate matter emission sources when the exhaust gases are not used to preheat kiln combustion air. Typical particulate control devices are cyclones, baghouses and wet scrubbers. Gaseous emissions from product coolers are considered negligible. (U.S. EPA 1985 and U.S. EPA 1987)

Hydrator (SCC 3-05-16-09 and 12):
Lime may be further processed to produce hydrated (slaked) lime. Atmospheric or pressure hydrators may be used. Water sprays or wet scrubbers are used to hydrate the lime, as they prevent product loss. After hydration, the product may be milled, dried and refined. Emissions from pressure hydrators may be higher than for atmospheric hydrators

because exhaust gases are sometimes released, making control more difficult. (U.S. EPA 1985)

Other Sources (SCCs 3-05-16-13,14,15,16 and 17):
Other potential sources include product transfer, conveying, screening, storage, packing and shipping and vehicular traffic.

## c) Inventory Approach

Particulate emissions from most Canadian lime manufacturing plants exceed 100 T/yr. Therefore, these plants should be inventoried as point sources of particulate matter and $SO_x$. Where possible, source test data should be used to estimate kiln or other process emissions.

For all other operations, and for those kilns where test data are not available, emission factors should be used for emission estimation in conjunction with site-specific operating and production information.

## d) Preferred Emission Estimation Procedure

Site-specific emission estimates may be based on the following information:

- site-specific process information, including specifics on process steps, process control used at each step, fugitive emission control procedures, rated efficiencies for any control procedures.
- site-specific emission information based on source testing, licensing information. This information must be representative of current operating conditions.
- raw materials volumes and lime production data (including scheduling if temporal data is required).
- fuel information (type and sulphur content).
- emission factors based on raw materials handling and production data are available in AP-42, Supplements A and B (U.S. EPA 1985), for controlled and uncontrolled particulate matter emissions

(and $NO_x$ and CO for kilns). Uncontrolled emission factors are available in the NAPAP report on criteria pollutant emission factors. (U.S. EPA 1987)

If control devices at a given facility differ from those for reported emission factors, then the uncontrolled emission factors should be used along with typical particulate removal efficiencies for the given control device. (U.S. EPA 1973)

For $SO_2$ emission estimation from kilns, AP-42 recommends the following:

- for kilns with only primary particulate matter control, sulphur dioxide may be estimated by a material balance using fuel sulphur content.
- when scrubbers are used <5% of the fuel sulphur will be emitted as $SO_2$, even with high sulphur coal. When other secondary collection devices are used about 20% of the fuel sulphur will be emitted as $SO_2$ with high sulphur fuels and <10% with low sulphur fuels.

Since kiln emissions are partially due to fuel combustion, the amounts of fuel used for lime production should be deducted from general industrial fuel consumption when inventorying that sector (see Section B.56.3).

### e) Activity Level

As stated in the previous section, the following site-specific activity level should be obtained:

- the consumption of raw materials and fuel.
- production data for lime, including the volumes hydrated.
- the types and amount of fuel used for the kiln.

### f) Alternative Emission Estimation Procedures

If base quantity data is not available for a given facility, Canadian lime plant capabilities and annual production data are reported by Energy, Mines and Resources (1989).

### g) Temporal Variability

Temporal data should be obtained though direct contact should be used to derive temporal factors.

### h) Geographic Variability

Lime plants are inventoried as point sources (see Section i).

### i) Point Source Establishments

The following lime manufacturers are listed in the Canadian Minerals Yearbook (EMR 1989). Plant ID numbers, where available, are from the Residual Discharge Inventory System maintained by Environment Canada.

| Province | Plant ID | Company Name | Location |
|---|---|---|---|
| New Brunswick | 130002 | Havelock Lime | Havelock |
| Quebec | 240025 | Domlin Inc. | St. Adolphe de Dadswell |
| | | Jolichaux Inc. | Joliette |
| Ontario | | The Algoma Steel Corp. Ltd. | Sault Ste. Marie |
| | | Beachville Limited | Ingersoll |
| | | General Chemical Canada Ltd. | Amherstburg |
| | | Guelph DoLime Ltd. | Guelph |
| | | Reiss Lime Co. of Canada Ltd. | Apragge |
| | | Steetley Quarry Products Inc. | Dundas |
| | | Stelco Steel | Ingersoll |
| | | Timminco Limited | Haley |
| Manitoba | | The British Columbia Sugar Refining Co.Ltd. | Fort Garry |
| | | Continental Lime Ltd. | Faulkner |
| | 460005 | Steel Brothers Canada Ltd. | (repeats?) |
| | 460004 | The Manitoba Sugar Co. Ltd. | ( " ) |

| | | | |
|---|---|---|---|
| Alberta | | The B.C. Sugar Refining Co. Ltd. | Taber |
| | | Continental Lime Ltd. | Exshaw |
| | | Summit Lime Works Ltd. | Hazell |
| | 480004 | Canadian Sugar Factories Ltd. | (repeats?) |
| | 480005 | Steel Brothers Canada Ltd. | ( " ) |
| | 480006 | Summit Lime Works Ltd. | ( " ) |
| British Columbia | | Continental Lime Ltd. | Pavilion Lake |
| | | BP Resources Canada Ltd. | Fort Langley |

## References - Section A.35.6

Energy, Mines and Resources, 1989. "The Canadian Minerals Yearbook 1988".

SNC/GECO Canada Ltd. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Criteria Pollutant Emission Factors. Volume 1, Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". EPA-600/7-87-015. Prepared by Radian Corporation. U.S, Environmental Protection Agency, Washington, D.C.

## A.36.1 METALLURGICAL COKE PRODUCTION (SIC 36990)

### a) General Description

Coke used for metallurgical processes is generally produced in Canada at integrated iron and steel plants using the slot oven coke by-product process. The process involves the destructive distillation of coal under pyrolytic conditions in a series of rectangular ovens arranged in parallel batteries. A solid coke residue is formed which is subsequently quenched and dried. During heating, the volatile constituents, expelled from the coal, are collected as fuel or recoverable by-products. Both particulate and gaseous emissions, including essentially all of the common air pollutants, can occur in the various coking operations. Although operations are cyclical for individual ovens, by-product yield is essentially continuous due to the large number of ovens within each battery.

### b) Process Description

Coal Preparation (SCC 3-03-003-09 to 13 and 3-03-003-16):
After unloading, coal is prepared by pulverizing, screening, blending and possibly preheating before charging. Particulate emissions from such processes are usually controlled by primary particulate control devices. The coal, used at Canadian coking operations, typically contains 0.3 to 1.2% sulphur (Environment Canada 1983). Coal is usually stored in piles on premises of the iron and steel plant, and precautions may be taken to minimize fugitive wind blown losses (e.g., surface wetting or dust suppressants).

Oven Charging (SCC 3-03-003-02):
During sequential charging, pulverized coal is loaded by larry car through individual top charging ports of the hot battery ovens. Charging requires approximately 10 seconds per oven, after which the top port is sealed. Off-gases during charging are generally contained by a battery collecting main that connects to the by-product plant. However, emissions of each of the common pollutants occur during charging.

Oven/Door Leaks (SCC 3-03-003-08):
Topside Leaks (SCC 3-03-003-14):

After levelling coal peaks in the oven and by heating with regenerated gases (i.e., COG) the coal is thermally distilled in the coking cycle that typically lasts for 15 to 18 hours to produce blast furnace coke and 25 to 30 hours to produce foundry coke. A positive back pressure is maintained to prevent air infiltration and door seals are used (e.g., patching, luting or other door seal mechanisms) to minimize leakage from the ovens. Amongst other common pollutant emissions, most of the hydrocarbon emissions are discharged during the coking phase.

Coke Pushing (SCC 3-03-003-03):

At the end of the cycle, hot coke is pushed from side doors of the ovens to railed quench cars. Travelling hoods or enclosed coke side sheds along the batteries are used for fugitive emission control at most plants. The sheds contain off-gases from coke pushing, as well as door leaks from only the pushing side of the battery and ducts lead to a stationary gas cleaner. Both particulate and gaseous emissions can occur during coke pushing, with the extent depending on the emission controls used and the degree of coking achieved.

Coke Quenching (SCC 3-03-003-04):

The hot coke is deluged with water at the quench tower located at the end of the batteries and finally crushed for use. Fresh quench water is normally used at Canadian plants, while at some facilities contaminated or partially contaminated make-up water (i.e., that can adversely affect particulate emission rates), may be used to quench coke. Along with other gaseous emissions, coke particles and dissolved solids in steam are emitted during quenching.

Coke Handling (SCC 3-03-003-12):

Fugitive particulate emissions also can be expected during crushing, screening and handling of the coke.

COG Consumption and Oven Underfiring (SCC 3-03-003-06):
At integrated plants, processes gases that evolve during coking are ducted to the by-product plant for recovery of tars, oils and other constituents of the raw coke oven gas. A portion of this gas is burned during oven underfiring while producing coke and the combustion product emissions are released at the battery stack. A portion of COG is also used for fuel in other integrated plant operations. Both particulate and $SO_2$ emission can be expected during combustion of COG with reduced $SO_2$ emissions in instances where COG is desulphurized at the by-product plant.

## c) Inventory Approach

Inventories of metallurgical coke production emissions should be done using point source methods, since emissions of most of the common pollutants exceed 100 tonnes/year at each facility. Direct source test data, material balances and emission factors have most often been used to estimate coke oven emissions.

## d) Preferred Emission Estimation Procedure

Specific reports and information which provide data to estimate emissions from metallurgical coke production include:

- various published and unpublished Environment Canada reports (Choquette 1974, Environment Canada 1983, Schultz International 1981 & 1982, ORF 1987, Edwards and Cotton 1988),
- emission factors by process reported by the U.S. EPA (1986 & 1987a),
- other U.S. reports in which emissions from specific coke oven operations are assessed (U.S. EPA 1981 & 1987b).

It is highly recommended to contact the major coke producers of the iron and steel industries and other non-integrated facilities in order to obtain plant-specific data such as:

- coal and coke production data with corresponding sulphur contents,
- facility characteristics by individual process with pertinent operating data including use and distribution of COG,
- control devices and efficiencies including methods and maintenance schemes employed to reduce fugitive emissions during both coal storage and coke production,
- emission test data that are available.

Facility emissions should be based upon measured data if available for a given process or calculated, where necessary, by reported emission factors. In instances where mass balance information is available and appropriate, emissions derived by emission factors should be confirmed. Because several of the release points are fugitive, cyclical and transient in nature, it is extremely difficult to collect representative samples with which to characterize coke oven emissions. Thus, other emission estimation techniques are often used.

Process emission factors for particulate matter, $SO_2$, $NO_x$, hydrocarbons and CO, along with corresponding control device efficiencies for operations at each plant have been reported by Environment Canada (1983 and internal files). The emission factors are based on the amount of the pollutant (kg) emitted per tonne of coal charged, except for coke handling operations which are determined as kg pollutant/tonne of coke produced. As facilities and controls may have been modified in recent years, plant-specific operating and other information should be acquired in order to confirm or update these factors. Controlled and uncontrolled emission factors for particulate and gaseous pollutants (with the same units as noted above) are reported in AP-42 (U.S. EPA 1986). Similarly, uncontrolled process emission factors for particulate and some additional gaseous emissions have been reported by U.S. EPA (1987a) which require information and application of specific control device removal efficiencies before use. In addition, either measurement data or specific emission algorithms should be used to estimate fugitive dust losses from coal storage piles with account of dust suppression techniques that may be employed. For example, algorithms have been developed and described in AP-42 (U.S. EPA 1986), as noted in Section A.09.1. Caution should be exercised when selecting and applying these factors and process activities should be defined with the assistance of plant contacts.

As noted elsewhere (Edwards and Cotton 1988), sufficient data may be available with which to conduct a simple hydrocarbon mass balance around the control envelope of the coking furnaces to check the total annual HC emissions calculated by emission factors. The difference between the mass of coal charged and the mass of coke and by-product (including COG) should approximate the total emissions from the processes. For example, it has been reported that the volatile components expelled during coking constitute 20-25% of the initial coal charge (IARC 1984, White et al 1975). Approximately 69% coke yield from coal is common. Similarly, a sulphur balance could be utilized to derive $SO_2$ emissions from coking and COG combustion using information such as:

- the sulphur content of coal charged and the fraction transferred to COG,
- the portions of COG burned during underfiring operations and combusted in other integrated plant operations.

Examples of certain operating conditions have been reported by U.S. EPA (1987a).

### e) Activity Level

The following published information is available for coke production:

- annual coal consumption and coke production statistics by individual companies (EMR 1986),
- provincial production data (Statistics Canada 1985).

However, more recent issues of these publications provide only Canada-wide coke production data (EMR 1989). thus, annual throughputs of coal and coke should be obtained directly from the producers.

### f) Alternative Emission Estimation Procedure

In the absence of direct producer information, emissions of the common air pollutants can be estimated from information contained in Environment Canada's internal files and or various reported emission factors (Environment Canada 1983, U.S. EPA 1986 and 1987a). Published Canadian base quantity data (EMR 1989) would require prorating to individual plants based upon previously reported statistics (EMR 1986) and on information from internal files of Environment Canada.

### g) Temporal Variability

Plant operating data should be used to estimate seasonal, daily and hourly temporal factors for metallurgical coke production. Generally, production is consistent throughout the year.

### h) Geographical Variability

Actual plant locations will be defined by compiling emissions on a point source basis.

### i) Point Source Establishments

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Nova Scotia | 120001 | Sydney Steel Corporation | Sydney |
| Quebec | 240160 | G.L.C. Canada Inc. | Berthierville |
| | 240014 | Societe Canadienne de Metarex Reynolds | Baie Comeau |
| Ontario | 351334 | Algoma Steel Corp. | Sault St. Marie |
| | 351105 | Dofasco Inc. | Hamilton |
| | 351106 | Stelco | Hamilton |
| Saskatchewan | 470002 | Bienfait Coal Company Ltd. | Bienfait |

## References - Section A.36.1

Choquette, P.J., 1974. "Air Pollution Emissions and Control Technology, Metallurgical Coke Manufacturing Industry". Environment Canada, Report EPA 3-AP-74-6.

Energy, Mines and Resources Canada (EMR), 1986. "Canadian Minerals Yearbook - Coal".

Energy, Mines and Resources Canada (EMR), 1989. "Canadian Minerals Yearbook - Coal - J.A. Aylsworth".

Environment Canada, Air Pollution Control Directorate, Pollution Data Analysis Division (unpublished information).

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10, Environmental Protection Programs Directorate.

International Agency for Research on Cancer (IARC), 1984. "IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans". Volume 34. IARC, Lyon, France. June.

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Report P-5134/FG prepared by Ontario Research Foundation for Inventory Management Division, Environment Canada.

Schultz International Ltd., 1982. "An Inventory of Air Contaminant Emissions from Industrial Sources in Alberta, Saskatchewan and Manitoba". Report prepared for Inventory Management Division, Environment Canada.

Statistics Canada, 1985. "Coal and Coke Statistics". Catalogue 45-002.

U.S. Environmental Protection Agency (U.S. EPA), 1981. "Coke Wet Quenching - Background Information for Proposed Standards". Draft EIS prepared by Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency (U.S. EPA), 1986. "Compilation of Air Pollutant Emission Factors - AP-42. Supplement A". October.

U.S. Environmental Protection Agency (U.S. EP:A) 1987a. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory". Report prepared by Radian Corp. NTIS PB 87-198735.

U.S. Environmental Protection Agency (U.S. EPA), 1987b. "Coke Oven Emissions from Wet Coal Charged By-Product Coke Oven Batteries. Background Information on Proposed Standards". Report EPA-450/3-85-028a prepared by Office of Air Quality Planning and Standards.

White, L.D., Stasikowski, M.J., Horstman, S.W. and Bingham E., 1975. "Atmospheric Emissions of Coking Operations - A Review". Report prepared by the Department of Health, University of Cincinnati Medical Centre, Cincinnati, Ohio.

## A.36.2 HOT-MIX ASPHALT PAVING PRODUCTION (SIC 36991)

### a) General Description

Hot-mix asphalt paving, also called asphaltic concrete paving or asphalt concrete, is a heated mixture of graded aggregate and asphalt cement (asphalt that is refined to meet specifications for paving, industrial and special purposes). It can be manufactured by the batch mix, continuous mix or drum mix process. These plants can be either permanent installations or portable. Particulate matter is the principal emission from these plants.

Cut-back paving operations, in which asphalt cement is liquified with petroleum solvents, are also a potential source of VOCs; however, this operation is not currently inventoried in Canada. In the U.S., cut-back paving operations are inventoried as area sources using simplified assumptions about emission factors (U.S. EPA 1989).

Asphalt production and blowing are inventoried as part of petroleum refineries. Asphalt roofing manufacture is also inventoried separately.

### b) Process Description (SNC/GECO and Ontario Research Foundation 1981)

Hot-mix asphalt plants are required to prepare aggregate and asphalt mix in desired proportions for surface paving of roads, etc. Conventional hot-mix asphalt plants operate with the following processes:

- heating and drying aggregate fillers (i.e., sand, fragments of stone and gravel),
- screening and classifying the hot aggregate into bins,
- measuring and mixing the aggregate in the desired proportions,
- transferring the hot mixture to trucks and, subsequently, transporting the product to the paving site.

Asphalt plants vary in the final mixing process, which may be done by either a batch or continuous mode of operation.

In recent years, a few drum mixing plants have been introduced to asphalt production which differ from the above processes in that the asphalt and the aggregates are heated and mixed in the dryer "drum" in a single step.

Emissions to the air from these operations have, to date, been inventoried as area sources under SCC 54100 (Asphalt Production - Fugitive) and SCC 54200 (Asphalt Production - Mixing). Particulate matter is the principal pollutant emitted from these plants.

Asphalt mixing plants produce both fugitive and direct particulate emissions from dryer operations. Fugitive particulates originate in screens, open bucket, elevators, weigh hoppers, asphalt heaters, storage piles and bins (Formica 1976), as well as traffic re-entrainment of yard dust. Most fugitive emissions, associated with the process, can however be eliminated when the sources are properly sealed (Robert et al 1975).

The primary source of particulate emissions is the dryer, where aggregate constituents are dried before mixing. Because a substantial percentage (70%) of particles are greater than 15 µm, primary control devices are generally used to remove these larger particles. The simplest and least costly dry collector is the expansion chamber which may also be fitted with one or more baffles, called skimmers, and are known to have efficiencies of up to 50% for particulates above 40 µm (Robert et al 1976). Cyclones are also used for primary collection of coarse particles, but finer fractions are removed with diminishing efficiencies in the order of 33% for particle sizes between 1 and 2.5 µm. For this reason, secondary control devices, such as centrifugal scrubbers and orifice scrubbers, are widely used which provide collection efficiencies of approximately 90% for particles >5 µm and 99.5% for those >10 µm, respectively. High energy venturi scrubbers are used less frequently, and fabric filters with efficiencies up to 99.9% for particles .0.5 µm are used to some extent (Robert et al 1976).

These plants are also minor sources of $SO_x$, $NO_x$, VOC and CO, relating mainly to the dryer and handling operations. Any emissions associated with fuel consumption of the asphalt heaters would normally be inventoried under industrial fuel combustion.

This sector may also be inventoried as point sources under the following SCCs:

| | | |
|---|---|---|
| 3-05-002-01 | Rotary Dryer, Conventional Plant | |
| 3-05-002-02 | Hot Elevators, Screens, Bins and Mixer | |
| 3-05-002-03 | Storage Piles | |
| 3-05-002-04 | Cold Aggregate Handling | |
| 3-05-002-05 | Drum, Dryer Hot Asphalt Plants | |
| 3-05-002-06 | Asphalt Heater | (Natural Gas) |
| 3-05-002-07 | " " | (Residual Oil) |
| 3-05-002-08 | " " | (Distillate Oil) |

## c) Inventory Approach

Asphalt hot-mix plants are inventoried as area sources of particulate matter, $NO_x$, $SO_x$, VOC and CO using emission factors based on tons of asphalt concrete produced.

## d) Preferred Emission Estimation Procedure

Uncontrolled particulate matter emission rates from the dryer of approximately 5% of the aggregated dried, have been previously estimated by Environment Canada (Robert et al 1976). This value, in conjunction with an average control device efficiency of 97%, can be used to estimate particulate matter emission rates from the dryers and assigned to SCC 54200 (?) (SNC/GECO and Ontario Research Foundation 1981).

In the 1985 inventory, Environment Canada used the particulate matter emission factors listed below for dryer emissions, based on the Mg of aggregate dried and province-specific information on control practices. An emission factor of 0.180 kg/tonne aggregate was used to calculate the fugitive emissions for all other operations. The dryer emission factors are:

| Province | Drying Factor (kg/Mg) |
|---|---|
| Newfoundland | 2.00 |
| Prince Edward Island | 5.00 |
| Nova Scotia | 2.00 |
| New Brunswick | 2.25 |
| Quebec | 1.75 |
| Ontario | 1.00 |
| Manitoba | 2.00 |
| Saskatchewan | 1.50 |
| Alberta | 0.21 |
| British Columbia | 1.25 |
| Yukon and North West Territories | 3.00 |

Fugitive particulate matter and all $SO_x$, $NO_x$, VOC and CO emissions may be evaluated using emission factors from the 1985 NAPAP inventory (U.S. EPA 1987).

### e) Activity Level

Canadian asphalt concrete production rates may be estimated from the asphalt sales in each province (Statistics Canada 45-004), excluding the asphalt used in roofing (Statistics Canada 45-001). In previous inventories (Environment Canada 1983, SNC/GECO and Ontario Research Foundation 1981), it has been assumed that asphalt concrete is 7% (by weight) asphalt, with the balance made up of aggregate fillers. Asphalt weighs 1048 kg/kL.

Asphalt used in construction is also reported in Statistics Canada publication 57-003.

## f) Alternative Emission Estimation Procedures

Asphalt hot-mix plants may be inventoried as point sources using the SCCs as described in Section b) and site-specific source data (preferred), or emission factors as described in Section e). Particulate control efficiencies are available in AP-42 (U.S. EPA 1985). Activity levels would be obtained directly from the producer.

If emissions from the asphalt heaters (SCC 3-05-002-06, 07 and 08) are included, the fuel use should be subtracted from the industrial fuel combustion totals.

## g) Temporal Variability

Asphalt sales data (Statistics Canada) is available on a monthly, quarterly and annual basis.

Hourly, daily and quarterly temporal factors are given for asphalt hot-mix production in a report by The MEP Company and Ontario Research Foundation (1985).

## h) Geographical Variability

Asphalt sales data are available on a provincial basis.

## References - Section A.36.2

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

Formica, P.N., 1976. "Controlled and Uncontrolled Emission Rates and Applicable Limitations for Eighty Processes". NTIS PB-266 378. As cited by SNC/GECO and Ontario Research Foundation, 1981.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Robert, J. et al, 1975. "Air Pollution Emissions and Control Technology Asphalt Paving Industry". Report EPS 3-AP742. As cited by SNC/GECO and Ontario Research Foundation, 1981.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, monthly. "Asphalt Roofing". Catalogue No. 45-001.

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U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". EPA-600/7-87-015. Prepared by Radian Corporation. U.S. Environmental Protection Agency, Washington, DC.

# A.36.3 PETROLEUM REFINERIES (SIC 36202)

## a) General Description

The petroleum refining industry converts crude oil feedstock to produce numerous types of marketable fuels and refined petroleum products by a wide variety of processes (U.S. EPA 1980, EPS 1987). After refining, these fuels and products are distributed to consumers through a marketing system (see Section A.51.1). On a national basis, the Canadian refining sector represents a significant source of $SO_2$ and HC emissions with a relatively lesser contribution of particulate, $NO_x$ and CO emissions. During 1988, there were 29 refineries operating in Canada. Component processes can differ significantly between each refinery, and only some of the following general process categories and specific operations are practiced at individual plants:

i) Separation Processes (e.g., atmospheric and vacuum distillation, light ends recovery/gas processing),

ii) Petroleum Treating Processes (e.g., hydrodesulphurization, hydrotreating, chemical sweetening, acid gas removal, de-asphalting),

iii) Petroleum Conversion Processes (e.g., thermal or catalytic cracking, reforming, alkylation, polymerization, isomerization, coking, visbreaking),

iv) Feedstock and Product Handling (e.g., storage, blending, loading, unloading),

v) Auxiliary Operations (e.g., boilers, wastewater treatment, hydrogen production, sulphur recovery, cooling towers, blowdown system, compressor engines).

The major direct process emission sources of common air pollutants include operations such as: vacuum distillation, coking, chemical sweetening, catalytic cracking, asphalt blowing and sulphur recovery. A substantial fraction of the emissions are also attributable to fugitive releases and fuel combustion equipment at refineries such as: utility boilers and process heaters. For inventories, these external combustion or in-process fuel combustion emissions are usually included with the petroleum refining sector, rather than the general industrial fuel combustion sector (see Section B.56.3). Accurate determination of refinery emissions is challenging, due to factors such as:

- the complexity of refinery processing with numerous points of direct and fugitive emission releases,
- defining the distribution and consumption of different fuel types (e.g., domestic and imported fuel/feedstocks) for the various thermal processes (e.g., gaseous, liquid or solid fuels, recycled process off-gases),
- allocating the quantity, mix and corresponding sulphur content of feeds to cracking units,
- defining the input/output content and/or process efficiencies for specific operations (e.g., sulphur recovery plants, hydro refining processes), where such facilities are available.

## b) Process Description

Vacuum Distillation Column Condensor (SCC 3-06-006-02 and 03): Crude oil is first separated into its major constituents by: atmospheric distillation, vacuum distillation and light ends recovery. High boiling point hydrocarbons from the atmospheric distillation column are directed to a vacuum column where distillation is accomplished at low pressure in a steam atmosphere to produce condensed components such as: lube distillates, residual oil, vacuum oil, asphalt stock, etc. The major HC and $SO_2$ emission sources related to the vacuum column include: steam ejectors and vacuum pumps that withdraw vapours through a condenser, while fugitive HC emissions also occur from leaking seals and fittings. The non-condensible vapours, formerly released to the atmosphere, are usually efficiently controlled by venting into blowdown systems, incinerators or waste heat boilers.

Blowdown Systems (SCC 3-06-004-01 and 02): Many of the refining process units subject to hydrocarbon discharges are manifolded into a collection unit (i.e., blowdown system), comprising a series of drums and condensers, whereby liquids are separated for recycling and vapours are recycled or flared with steam injection. Uncontrolled blowdown emissions consist primarily of hydrocarbons, while vapour recovery and flaring systems release lesser HC and greater combustion products including $SO_2$, $NO_x$ and CO.

Catalytic Cracking (SCC 3-06-002-01, 3-06-003-01 and 3-06-012-01): Catalytic cracking, with heat and pressure, converts heavy oils from distillation and other processes to gasoline and distillate blends. Fluidized-bed catalytic cracking (FCC) processes use finely divided catalysts that are suspended in a riser with hot vapours of the fresh feed. The vapour reaction products of the desired molecular weight are separated from the catalyst particles in cyclones and transferred to the fractionator section of the conversion process, where fuel oils are split from gasoline and other fuels. The spent catalyst is conveyed to a regenerator unit, in which deposits are burned off before recycling. Moving-bed catalytic cracking (TCC), used at one Canadian refinery, involves co-current mixing of the hot feed vapours with catalyst beads that flow to the separation and fractionating sections of the unit. In a fluid coking process used at one refinery, residual oil feeds are thermally cracked to yield vapour products and coke fines which are separated from the fractionated vapours, devolatilized and gasified. In addition to process heaters, emissions of the common pollutants from catalytic cracking occur in flue gases of the catalyst regeneration units. Particulate emissions are controlled by cyclones or ESPs, CO and HC emissions are controlled by CO wasteheat boilers, in conjunction with CO promoter usage, and scrubbers may be used to remove $SO_2$ emissions. Volatile material from fluid coking unit gasifiers are treated for particulate and sulphur removal.

Sour Water Stripping (SCC 3-06-005-XX): In various hydro-refining and other treating processes, sour water containing sulphides, ammonia and other contaminants is stripped by steam in a one or two-staged trayed or packed tower. The stripped hydrogen sulphide gases may be incinerated or directed to sulphur recovery plants. $SO_2$, and possibly HC emissions, are the primary pollutants released from the stripping process.

Sulphur Recovery (SCC 3-01-032-01 to 04): Sulphur recovery plants (i.e., either on or off-site) are used to convert hydrogen sulphide within refinery gas streams to elemental sulphur as a by-product. Either a two, three or four-stage Claus plant is used to catalyze the reaction. The release of $SO_2$ emissions in the tail gas will depend on the efficiency of the sulphur recovery system. When such facilities are on-site, associated emissions should be included with total petroleum refinery emissions.

Flares (SCC 3-06-009-03 and 04): Both natural gas and process gases may be flared from processes such as: vacuum distillation, blowdown systems, decoking operations and other equipment. Although flare emissions are thought to consist primarily of hydrocarbons, other pollutants are also expected to be released. Steam may be injected to the combustion zone, which provides turbulence and inspirated air, in order to achieve more complete combustion or smokeless flares.

Asphalt Blowing (SCC 3-06-011-01): Asphalt is produced at some refineries whereby asphaltic residual oils (i.e., after vacuum distillation and de-asphalting processes) are polymerized and oxidized by blowing preheated air through the batch or continuous feed. Hydrocarbon vapours are released with the blowing air, and these vapours may be incinerated or removed by scrubbing.

Numerous fugitive hydrocarbon emissions occur at petroleum refineries, some of which include:

Process Drains and Wastewater Separators (SCC 3-06-005-03 to 06)
Valves, Flanges, Pump/Compressor Seals (SCC 3-06-008-XX)
Cooling Towers (SCC 3-06-007-01 and 02)

Fugitive emission sources from equipment and transfer lines dispersed throughout the refineries, include: valves of all types (e.g., open-ended, pipeline, vessel relief), flanges on gas and liquid transfer lines and vessels or containers, compressor and pump seals (e.g., natural gas-fired reciprocating or gas turbine engines), evaporative emissions from open process drains, ponds, spills and cooling tower water systems. Such fugitive emissions (i.e., mainly hydrocarbons) are generally controlled by routine maintenance practices and equipment changes or seal replacements, minimizing leaks and spills through improved procedural and housekeeping efforts, as well as collecting and venting open source emissions through available control devices.

Product Storage Tanks: Hydrocarbon emissions originate from working and breathing losses associated with feedstock and product storage vessels in refinery tank farms. The emissions will depend on the tank design (e.g., internal or external floating roof), the type of material stored, control practices employed and other factors. The associated emissions should be included with other petroleum refinery emissions, and specific inventory procedures are discussed in the petroleum marketing sector description (see A.51.1).

Process Heaters and Boilers (SCC 3-06-001-XX): Process heating furnaces are used extensively in refineries to supply heat for raising the temperature of feed materials to be reacted or distilled. Depending on several requirements, the fuels may include: in-process refinery gas, CO rich regenerator gas, natural gas, residual oils or other combinations. Similarly, fuels are combusted at refinery utility plants, in order to supply process steam for heating and separating hydrocarbon streams. All of the common air pollutants are emitted from these fuel combustion sources (see also Section B.56.3).

### c) Inventory Approach

Inventories of petroleum refinery emissions should be done using point source methods, since emissions of most of the common pollutants exceed 100 tonnes/year at each facility. Material balances, direct source test data and emission factors have most often been used to estimate refinery emissions by process. Accordingly, these same techniques are recommended with cross-checking between methods, where possible.

### d) Preferred Emission Estimation Procedure

Specific reports and information which provide data to estimate emissions from petroleum refineries include:

- various published and unpublished Environment Canada reports (EPS 1983 and 1987), SNC/ORF 1981, ORF 1987, Edwards and Cotton 1988),
- specific PACE reports in which petroleum refining process and fuel combustion emissions have been derived for the years 1983 and 1988 (PACE 1985, Kosteltz 1991),
- controlled and uncontrolled emission factors in AP-42 (U.S. EPA 1977 and 1980),
- uncontrolled emission factors reported for the 1985 NAPAP inventory (U.S. EPA 1987),
- sulphur contents of fuels (RTM 1988).

In order to derive as accurate emissions as possible, it is highly recommended to contact the individual producers. For example, questionnaire surveys of the petroleum refinery industry have been conducted by PACE in separate years, in order to procure pertinent information from the individual facilities and emission rates that have been estimated by the producers. Examples of information that have been or might be requested are:

- a description of the process including changes from the most recent survey,
- emission estimates for relevant sources at the refinery, with calculation methods and back-up information (e.g., source test data, information to calculate emissions and control device types/efficiencies),

- base quantities or throughputs by process (e.g., nominal fresh feed daily capacities for individual process units) and annual feed and product quantities,
- pertinent sulphur balance information (e.g., identification of the type, origin, sulphur content and API gravity of crude oil inputs and purchased materials, the amounts and sulphur content of individual products such as sulphur in fuels produced and other recovered products, the corresponding emission points), as discussed below,
- the types, quantities and sulphur contents of fuels burned in boilers and heaters, corresponding to the specific emission point,
- the quantity and sulphur content of feedstock processed by catalytic cracking units,
- the amount and composition of acid gas feed to sulphur recovery units in conjunction with the amount of elemental sulphur produced (i.e., plant recovery efficiency) along with the amount/ composition of tail gas being incinerated,
- the quantity and sulphur content of flared tail gases,
- information relevant to refinery fugitive emission sources (e.g., equipment counts and characterization of valves, flanges, pump/compressor seals, process drains, etc., with associated emission control seal estimates or maintenance schemes practiced),
- data related to storage tank emissions (e.g., types and characteristics of materials stored, the size/type/characteristics of storage vessels and types of vapour conservation devices used).

Facility emissions should be based upon measured data, where available, for a given process or calculated by material balance or reported emission factors, where necessary. For example, sulphur mass balances for individual processes are expected to provide the most reliable $SO_2$ emissions, where source test data are lacking, and refineries typically maintain daily sulphur balances. However, difficulties might be anticipated in deriving $SO_2$ emissions for sources such as vacuum distillation and flares (i.e., emission factors may be preferred for these and fuel combustion sources). Similarly, particulate emissions data can be determined for catalyst regeneration units based on daily material balances. On the other hand, published emission factors and algorithms should be used to estimate emissions of $NO_x$, CO and hydrocarbons from most sources, in conjunction with related control device efficiency information for operations at each plant. Methods to calculate fugitive HC emissions from small release points and storage tanks are discussed in Section A.51.1, and in other reports (PACE 1985, Edwards and Cotton 1988, Kosteltz 1991). Caution should be exercised when selecting and applying published emission factors (e.g., U.S. EPA 1980 and 1987) under Canadian conditions and process activities should be defined with the assistance of plant contacts or applicable survey data. In most cases, process emission factors are based on the mass of pollutant emitted per volume of refinery feed. Some factors are based on other unit quantities (e.g., amount of product or other material processed).

### e) Activity Level

Throughputs of fuels and process feedstocks, as well as specific product amounts, at each refinery should be obtained directly from the producers or provincial agency files. In the absence of producer information, the following reported or published information may be used to obtain or derive base quantity data:

- Statistics Canada reports for provincial crude oil throughputs,
- specific process throughputs, fugitive sources and fuels burned by refinery for selected years (PACE 1985, Kosteltz 1991),
- Oilweek publications for daily capacities by process and refinery,
- Energy, Mines and Resources report for sulphur production by province for refineries (EMR 1989),
- individual refinery daily capacities by selected processes (Southern Energy Group 1990).

## f) Alternative Emission Estimation Procedure

Emissions of the common air contaminants can be estimated for processes of individual refineries on the basis of plant/process capacity information or prorated base quantities to a given base year and published emission factors. It is recommended to use AP-42 emission factors (U.S. EPA 1980), in conjunction with estimated process/control device efficiencies, for most of the pollutants. On the other hand, it is currently recommended to use HC emission factors derived for the NAPAP study to calculate the process emissions of hydrocarbons. Methods for deriving fuel combustion and fugitive HC emissions are discussed in Sections B.56.3 and A.51.1., respectively.

## g) Temporal Variability

Plant operating data should be used to estimate seasonal, daily and hourly temporal factors for petroleum refining operations. Although most plants operate constantly throughout the year, temporary or permanent unit shut-downs occur at specific plants.

## h) Point Source Establishments

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Newfoundland | | Come-by-Chance | Come-by-Chance |
| Nova Scotia | 120011 | Esso Petroleum Canada | Dartmouth |
| | 120010 | Ultramar Canada | Halifax |
| New Brunswick | 130012 | Irving Oil Ltd. | Saint John |
| Quebec | 240073 | Petro-Canada Products | Pointe-aux-Trembles |
| | 240072 | Shell Canada | Montreal |
| | 240075 | Ultramar Canada | Ste. Romuald |
| Ontario | 351031 | Esso Petroleum Canada | Sarnia |
| | 351271 | Petro-Canada Products | Clarkson |
| | 351270 | Petro-Canada Products | Trafalgar/Oakville |
| | 351034 | Shell Canada | Sarnia |
| | 351032 | Sunoco/Suncor | Sarnia |
| | 351100 | Texaco Canada | Nanticoke |
| Saskatchewan | 470029 | Federated Cooperatives | Regina |
| | | Petro-Canada Products | Moose Jaw |
| Alberta | 480164 | Esso Petroleum Canada | Strathcona |
| | 480024 | Husky Oil | Lloydminster |
| | | Parkland Industries | Bowden |

| | | | |
|---|---|---|---|
| | 480162 | Petro-Canada Products | Edmonton |
| | 480163 | Shell Canada | Scotford |
| | 480160 | Turbo Resources | Calgary |
| British Columbia | 590039 | Chevron Canada | Burnaby |
| | 590040 | Esso Petroleum Canada | Ioco |
| | 590462 | Husky Oil | Prince George |
| | | Petro-Canada Products | Port Moody |
| | | Petro Canada Products | Taylor |
| | | Shell Canada Products | North Burnaby |
| North West Terr. | | Esso Petroleum Canada | Norman Wells |

## References - Section A.36.3

Edwards, W.C. and Cotton, J., 1988. "VOC Emissions Methods Manual". Report prepared by B.H. Levelton & Assoc. Ltd. for Environmental Analysis Branch, Environment Canada.

Energy, Mines and Resources Canada (EMR), 1989. "Canadian Minerals Yearbook - Sulphur Preprint".

Environment Canada (EPS), 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10, Environmental Protection Programs Directorate.

Environment Canada (EPS), 1987. "Environmental Status Report for the Canadian Petroleum Refining Industry 1983-1984". Report EPS 1/PN/1 prepared by Industrial Programs Branch, Conservation and Protection.

Kosteltz, A., 1991. Private Communication. (PACE/Environment Canada 1988 Petroleum Refinery Atmospheric Emissions).

Oilweek, "Refinery and Petrochemical Report".

Ontario Research Foundation (ORF), 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Report P-5134/FG prepared for Inventory Management Division, Environment Canada.

Petroleum Association for Conservation of the Canadian Environment (PACE), 1985. "Canadian Petroleum Refineries Atmospheric Emission Survey 1983". PACE Report No. 85-1 prepared by W.J. Grant.

RTM Engineering Ltd. (RTM), 1988. "Review of Sulphur Content of Petroleum and Synthetic Fuels 1978-1987". Report prepared for Environment Canada.

SNC Geco/Ontario Research Foundation (SNC/ORF), 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Report prepared for Pollutant Data Analysis Division, Environment Canada.

Southam Energy Group, 1990. "Energy in Canada 1990-1991". Southam Business Information and Communications Group Inc.

Statistics Canada. "Quarterly Report on Energy Supply-Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1977. "Compilation of Air Pollutant Emission Factors - AP-42" + Supplement 12 (1980).

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emission Inventory". Report prepared by Radian Corp. NTIS PB 87-198735.

## A.37.1 CARBON BLACK PRODUCTION (SIC 37111)

### a) General Description

Carbon black, a finely divided carbon produced by the thermal decomposition of hydrocarbons, is a major industrial chemical used primarily as a reinforcing agent in rubber compounds, especially tires. Two types of processes are currently used in Canada for carbon black production: thermal and oil-furnace. Emissions of particulate matter, CO, $NO_x$, $SO_2$ and VOCs are inventoried for this sector.

### b) Sector Description (U.S. EPA 1985)

In the oil furnace process, an aromatic liquid hydrocarbon feedstock is heated and injected continuously into the combustion zone of a natural gas-fired furnace, where it is decomposed to form carbon black. Primary quench water cools the gas to stop cracking. The exhaust gases entraining the carbon particles are further cooled by passage through heat exchangers and direct water sprays. The carbon black is then separated from the gas stream, usually by a fabric or bag filter. A cyclone for primary collection and particle agglomeration may precede the filter. A single collection system often serves several manifolded furnaces. A portion of the baghouse (filter) effluent stream may be returned for product drying (see below), but most is vented to the atmosphere. A flame or incinerator may be used after the baghouse in some plants for contaminant control. The raw carbon black collected in the bag filter unit then undergoes further processing, such as pulverizing, drying, pelletizing and packaging.

Potential emission points, in addition to the main process vent, include oil storage tank vent gas, fugitive emissions, pneumatic system vent gas, dryer vent gas and vacuum cleanup system vent gas.

The thermal process is a cyclic operation in which natural gas is thermally decomposed, or cracked, into carbon particles, hydrogen and a mixture of other organics. Two furnaces are used in normal operation. The first cracks natural gas and makes carbon black and hydrogen. The effluent gas from this reactor is cooled by water sprays and the black is collected in a fabric filter. The filtered gas is used as a fuel to heat the second reactor. When the first reactor becomes too cool to crack the natural gas feed, the positions of the reactors become reversed and the second reactor is used to crack the gas while the first is heated. Emissions from the furnaces in this process are very low because the off-gas is recycled and burned in the next furnace to provide heat for cracking, or sent to a boiler as fuel. The collected thermal black is pulverized and pelletized to a final product in much the same manner as furnace black.

The following SCCs are used to inventory carbon black production:

| SCC | Description |
|---|---|
| 3-01-005-02 | Thermal Process |
| 3-01-005-04 | Oil Furnace Process (Main Process Vent) |
| 3-01-005-06 | Transport Air Vent |
| 3-01-005-07 | Pellet Dryer |
| 3-01-005-08 | Bagging/Loading |
| 3-01-005-09 | Furnace Process Fugitive Emissions |

### c) Inventory Approach

Carbon black plants are inventoried as point sources of particulate matter, CO, $NO_x$, $SO_x$ and VOC. Emission factors based on the amount of carbon black produced are used in the absence of site-specific emission rates based on source testing.

### d) Preferred Emission Estimation Procedure

In recent inventories, Environment Canada has developed site-specific emission factors for Canadian carbon black plants (e.g., Environment Canada 1983, ORF 1987). These were based on internally available questionnaire data.

## e) Activity Level

There are two carbon black plants in Canada (see section i)). Annual production rates may be obtained through direct contact.

## f) Alternative Emission Estimation Procedures

Alternative emission factors are available in AP-42, in Table 5.3-3 (U.S. EPA 1985).

## g) Temporal Variability

No temporal factors specific to carbon black production were identified in the literature.

## h) Geographical Variability

Carbon black production facilities are inventoried as point sources (see Section i)).

## i) Point Source Establishments

Currently, there are two carbon black production facilities, both in Ontario:

| | |
|---|---|
| Cabot Carbon of Canada Ltd. | Sarnia |
| Columbian Carbon | Hamilton |

## References - Section A.37.1

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Ontario Research Foundation, 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emissions Inventory for Sources in Eastern Canada". Report prepared for Environment Canada. Report P-5134/FG.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

## A.37.2 SULPHURIC ACID PRODUCTION (SIC 37119)

### a) General Description

Sulphuric acid, used mainly for fertilizers and wood pulping, is made by the contact process in Canada by burning elemental sulphur at various chemical plants or containing primary metal smelter off-gases. Methods for deriving sulphur burning plant emissions are discussed below, while emissions associated with smelter acid plants should be addressed in separate sectors. Along with acid mist, $SO_2$ is the major type of emission from $H_2SO_4$ plant operations (Environment Canada 1983, U.S. EPA 1985). Particulate matter and $NO_x$ are also emitted from these operations (U.S. EPA 1987).

### b) Process Description

<u>Absorption Tower</u> (SCC 3-01-023-01 to 18):
Elemental sulphur (e.g., feedstock from refineries), initially melted and processed to remove ash, is burned in a furnace with clean, dry air to produce sulphur dioxide. After cooling, the gases enter a staged solid catalyst (vanadium pentoxide) convecter where $SO_2$ is catalytically oxidized to sulphur trioxide (i.e., conversion of usually 95 to 98% $SO_2$). The cooled converter exit gas, containing $SO_3$, is then absorbed in a strong (98-99%) aqueous solution of sulphuric acid to form a higher $H_2SO_4$ concentration product. Most emissions (i.e., unreacted $SO_2$, unadsorbed $SO_3$ and $H_2SO_4$ mist) occur from the absorption tower exit stack with quantities depending on factors such as: the quality of sulphur feedstocks, $SO_2$ conversion efficiency, process temperatures and pressures, throughputs and $SO_3$ absorption efficiencies, types and efficiencies of emission control devices, as well as other plant-specific parameters. Acid mist may be controlled with electrostatic precipitators or fibre mist eliminators and $SO_2$ emissions may be controlled with in situ sodium sulphite/bisulphite scrubbers. Alternatively, some plants use a dual absorption process to increase $SO_2$ conversion efficiency and thereby decrease $SO_2$ emissions. Other minor fugitive $SO_2$

emissions have been reported for tank car and truck unloading (SCC 3-01-023-20) and storage tank vents (SCC 3-01-023-21) (U.S. EPA 1987).

## c) Inventory Approach

Since $SO_2$ emissions of most sulphuric acid plants have been reported to exceed 100 tonnes/year (Environment Canada 1983, ORF 1987), inventories of $H_2SO_4$ plant emissions should be done using point source methods. It is recommended to verify or compare plant-specific emissions data using published emission factors for the types of processes involved.

## d) Preferred Emission Estimation Procedure

Information sources that can be used to calculate emissions include:

- specific unpublished emission factors developed by Environment Canada based on survey data (Environment Canada 1983 & 1985, ORF 1987),
- controlled and uncontrolled emission factors reported in AP-42 (U.S. EPA 1985),
- summarized uncontrolled emission factors reported for the NAPAP inventory (U.S. EPA 1987).

It is recommended to directly contact the individual producers in order to compile accurate emissions and procure appropriate data such as:

- plant production data including the amounts and type of sulphur feedstocks, the annual throughput and concentration of $H_2SO_4$ produced (i.e., 98 or 99% acid), oleum production, spent acid burning volumes,
- plant-specific process data (e.g., single or dual contact process, typical $SO_2$ conversion efficiencies, other processing facilities such as spent acid or $H_2S$ burning),
- emission control devices used and expected efficiencies for acid mist and $SO_2$ and particulate matter

- any reliable emission test data that can be made available (e.g., converter inlet/exit $SO_2$ gas concentrations).

Average plant-specific controlled emission factors have been developed by Environment Canada, based on survey questionnaire data, that range from 3.52 to 31 kg $SO_x$ per tonne of $H_2SO_4$ produced. These correspond to average $SO_2$ to $SO_3$ conversion efficiencies, ranging from 93 to near 100% depending on the type of plant process, controls used, etc. New or modified plants in the U.S. are required to emit less than 2 kg $SO_x$/tonne of 100% $H_2SO_4$ produced (i.e., equivalent to 99.7% conversion efficiency).

Plant-specific emission factors and emissions data can be updated using the procured information noted above and the application of emission factors or nomograph technique reported by U.S. EPA (1985). These uncontrolled factors have been developed from source testing/$SO_2$ conversion efficiency relationships and require further account of control device removal efficiencies, where appropriate. Similarly, both uncontrolled and controlled acid mist emission factors are reported (U.S. EPA 1985) and should be used to estimate corresponding emissions where direct source test data are lacking. Fugitive $SO_2$ emission factors, reported by U.S. EPA (1987), should also be applied to account for releases associated with product handling operations.

### e) Activity Level

Published production data can be obtained from:

- Environment Canada files based on unpublished survey information (Environment Canada Internal Files),
- total $H_2SO_4$ production and plant capacity information (Can.Min.J. 1989),
- total Canadian export of $H_2SO_4$ and limited plant data (EMR 1989),
- Statistics Canada (1989).

It is recommended to contact individual producers, in order to obtain relevant base quantity and operating data which may be based on either the amount of sulphur burned or, preferably, the amount and grade of sulphuric acid produced. Other sources of information noted above may not provide sufficient base quantity data for an accurate emission calculation.

### f) Alternative Emission Estimation Procedure

Emissions associated with sulphuric acid production can be estimated in instances where less accurate data are required (e.g., without plant contact or response), using published emission factors and Canadian production data. It is recommended to use U.S. EPA (1985) emission factors (i.e., assuming 98% $SO_2$ to $SO_3$ conversion efficiency) in conjunction with annual $H_2SO_4$ export data (EMR 1989) prorated by specific plant capacity information (EMR 1986).

### g) Temporal Variability

Operating information (e.g., seasonal, daily and shift-related operations) should be obtained through individual plant contact, in order to temporally resolve emissions.

### h) Geographical Variability

The locations of individual plants are known with which to geographically assign emissions.

### i) Point Source Establishments

The following $H_2SO_4$ producing plants have been assembled from the Environment Canada point source list 1990) and other reported information (EMR 1989, Can. Min. J. 1989). Stack parameter data (i.e., absorption tower stack data) should be acquired from the producers).

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240055 | CIL Inc. (Beloeil) | McMasterville |
|  | 240056 | NL CHEM Inc. | Varennes |
| Ontario |  | Sulco Chemicals Ltd. | Elmira |
| Manitoba | 460009 | Border Chemical Co. Ltd. | Transcona |
| Saskatchewan | 470045 | Eldor Mines Sulphuric Acid Plant | ? |
|  | 470004 | Gulf Minerals Ltd. | ? |
|  | 47046 | Key Lake Sulphuric Acid Plant | Key Lake |
|  |  | Comeco | Rabbit Lake |
| Alberta | 480156 | CIL Inc. (Marsulex Inc.) | Ft. Saskatchewan |
|  | 480013 | Esso Chemical Ltd. | Redwater |
|  | 480010 | Sherritt Gordon Mines Ltd. | Fort Saskatchewan |
|  | 480012 | Western Co-op. Fertilizers Ltd. (still operating?) | Calgary |
|  | 480012 | Western Co-op. Ltd. | ? |
| British Columbia |  | CIL Inc. (Westcoast Energy Inc.) | Prince George |

## References - Section A.37.2

Energy, Mines and Resources, Canada (EMR), 1986. "Canadian Minerals Yearbook - Sulphur".

Energy, Mines and Resources, Canada (EMR), 1989. "Canadian Minerals Yearbook - Sulphur - M. Prud'homme".

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10, Environmental Protection Programs Directorate.

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## A.37.3 PLASTIC FABRICATION (SIC 37312)

### a) General Description

This sector includes the operations used in the fabrication of items from polymers and resins. Typical operations are:

- extrusion
- injection moulding
- blow moulding
- foam forming
- laminating of composite materials
- plastic coating
- phenol/formaldehyde adhesives
- urea/formaldehyde adhesives
- tire and rubber industry

Only VOC emissions associated with these operations are inventoried under this sector. Emissions from fuel combustion in this sector are inventoried under Industrial Combustion (B-56-3). The production of the polymer material or resins is included in the Organic Chemical Industry Sector (SIC 37120). The phenol/formaldehyde and urea/formaldehyde adhesives are somewhat distinct from the solvent-based adhesives which are included in the Adhesives sub-sector of the General Solvent Use Sector (SIC 65321). These cross-linking adhesives contain monomer compounds which polymerize with the application of heat; they do not generally contain solvents which form the basis of solution-type glues and adhesives.

Table A.37.3-1 shows the resins processed in Canada into fabricated items, examples of which are provided in the table.

Some plastic coating operations should be included in this sector (acrylic coatings, for example), while others such as epoxy coating should be inventoried as a paint under the Application of Surface Coatings Sector (SIC 42751).

VOCs are the principle emissions from this sector.

## b) Process Description

These resins are transformed into products using different processes: Extrusion (films, sheet or dye) moulding (blow or injection), paper coating, foam blowing, forming (vacuum or thermo), lamination and fibre spinning.

In general, very little solvent is used in this sector. Emissions will either be: raw materials present in the resins as residue, blowing agents used to produce foams and plasticizers which are low volatility chemicals added to the resins to make them more flexible.

Lamination and fibre spinning are two categories of processes where solvents may be used. (CCME 1990)

Table A.37.3-2 summarizes the typical operations performed in plastics fabrication and Table A.37.3-3 is a partial list of SICs which may involve plastic fabrication. Some establishments may produce raw plastic material as well as finished fabricated plastic goods. The emissions due to the process and fabrication should be separately estimated with only the fabrication emissions being included in this sector. The process emissions should be accounted for in the Organic Chemical Industry Sector (SIC 37120). Not all plastic extrusion should be considered fabrication, since many raw plastics are extruded and cut into pellets as part of the production process (polyethylene and polypropylene, for example).

One of the largest emission sources is film extrusion, which presents to the atmosphere a very thin, hot film. Injection moulding and blow moulding are small emitters of VOC.

In the case of polyester/fibreglass composites, emissions of the monomers are from exposed surfaces before the polyester has fully polymerized. Other VOC emissions are also due to solvents used for clean-up. U.S. EPA (1987) provides the NAPAP emission factors for a number of fabrication processes.

The following SCC codes are available for this sector:

| | |
|---|---|
| SCC 3-08-001-XX | Tire Manufacture |
| SCC 3-08-007-XX | Fabricated Plastic Products/Fibre Glass Resin Products |
| SCC 3-08-008-XX | Plastic Foam Products |
| SCC 3-08-009-XX | Fabricated Plastic Products |

A more comprehensive list of emission factors (as well as 1985 emissions) for this sector are provided in Table A.37.3-4, from CCME (1990). These emission factors are partly based on recent information from the plastics industry.

### c) Inventory Approach

The VOC emission factors provided in Table A.37.3-4 should be used to inventory emissions from this sector. For tire production, U.S. EPA (1987) NAPAP emission factors should be used. The main task in preparing the inventory is to compile reliable base quantity data for each of the resins. CCME (1990) provides an estimate of the 1985 volumes of resins processed in Canada. These estimates, which do not include tire manufacture, were provided by the Environment and Plastics Institute of Canada (EPIC). Other sources of production/processing data are Statistics Canada and industrial associations such as the Canadian Chemical Producers Association. Area source methodology is used except for large establishments such as tire producers.

### d) Preferred Emissions Estimation Procedure

Reliable estimates of the volumes of the various resins processes in the inventoried year must be compiled, in order to use the emission factors in Table A.37.3-4. The processed volumes of each resin should be further subdivided according to the operations in Table A.37.3-4. Such detailed data will not be readily available without a survey of the plastic fabricators. In view of the large number of small fabricating operations, such a survey would not be feasible, except for selected establishment such as tire producers. Instead, it is recommended that total volumes processed for each resin be compiled using sources such as:

Statistics Canada: 46-222
46-002
47-006

Canadian Chemical Producers Association

Environment and Plastics Institute of Canada

Some of these sources may provide some further detailed information as to the processes used. Table A.37.3-4 provides the amount of each resin processed in 1985 as a percentage of total resin. Also provided is a percentage breakdown of the processes used for each resin. In view of changing consumer attitudes, particularly with regard to plastic packaging, these percentage breakdowns should be used with caution. Where only the total processed amount of a particular resin or of all resins is available on an industry-wide basis, the amounts of each resin used in each process can be estimated using the percentage breakdowns in Table A.37.3-4. The comparison in Table A.37.3-5 of the distribution of U.S. resin processes (for 1978) (Edwards and Cotton (1989)) with the process percentages in Table A.37.3-4 for Canada in 1985, show that large changes in the distribution of fabrication operations are not expected. Once a breakdown of the quantities of resin processed and the operations used in fabrication has been prepared, the application of the VOC emission factors in Table A.37.3-4 is straight-forward.

### e) Activity Level

Processing activity is reflected in the statistical data, as discussed in Section d).

### f) Alternative Emissions Estimation Procedure

Where a less detailed inventory approach is required, the subdivision of the total resins processed into individual resins and processes can be avoided by using a composite emission factor. From Table A.37.3-4 the overall emission factor for plastics fabrication is 6.9 gVOC/kg resin processed.

While this factor provides a rapid estimate, the lack of detail on the resins processed does not permit any assessment of the actual hydrocarbons likely to be emitted.

### g) Temporal Variability

The quarterly or monthly resin shipments or production statistics may be available from Statistics Canada (Publication 46-222, 46-002 or 47-006, for example). These statistics can be used to apportion annual emissions on a seasonal or monthly basis. Diurnal and day-of-week activity variations are provided in MEP/ORF 1986.

### h) Geographical Variability

The national emissions can be distributed to provinces using processing capacity by province, provided in Statistics Canada 46-222. Tire producers can be located as individual establishments. Gridding of the emissions to sub-provincial scales can be achieved using gridded labour force statistics.

## TABLE A.37.3-1

## Resins Processed in Canada

| Resin | Example of Products |
|---|---|
| Polyethylene | Packaging materials (containers, bottles), garbage bags |
| Polyvinylchloride | Vinyl siding, window frames, pipes, packaging film |
| Polystyrene | Insulation, packaging, serviceware (cups) |
| Polypropylene | Transparent films |
| Polyesters | Fibreglass, fibres, bottles |
| Acrylonitrile-Butadiene-Styrene (ABS) | Pipes, telephones, machine housings |
| Urea-Formaldehyde | |
| Polyurethane | Foams |
| Polyamide | Nylon fire |
| Phenol formaldehyde | "Bakelite" electrical equipment |
| Acrylic | Fibres |
| Epoxy | Laminates |
| Polycarbonate Polyphenylene | Helmets |
| Acetal | Gears |

(CCME 1990)

## TABLE A.37.3-2

## Plastic Fabrication Processes
(CCME 1990)

| | Extrusion | Moulding | | Moulding | Coating | Forming (Thermo-plastic) | Laminates | Adhesives |
|---|---|---|---|---|---|---|---|---|
| | | Injection | Blow | | | | | |
| Polystyrene | | X | X | | | | | |
| Polyethylene | X | | | X | | | | |
| Polyester | | | | | | X | X | |
| Polyvinylchyloride | X | X | | | | | | |
| Polypropylene | X | X | | | | | | |
| ABS | X | | | X | | | | |
| Acetal | | | | X | | | | |
| Acrylic | | | | | X | | | |
| Epoxy | | | | | X | | X | |
| Phenolformaldehyde | | | | X | | | X | X |
| Polyamide | X | | | X | | | | |
| Polycarbonate | | | | X | | | | |
| Polyesters | | | | | | X | | |
| Polyphenylene | | X | | | | | | |
| Polyurethane | | X | X | | | X | | |
| Urea formaldehyde | | | | X | | | | X |

## TABLE A.37.3-3

## Sectors Involving Plastics Fabrication

| SIC | |
|---|---|
| 16110 | Foamed and expanded plastic products |
| 16210 | Plastic pipe and pipe fittings |
| 16300 | Tire and tube manufacturers |
| 20400 | Paper conversion products |
| 37312 | Plastic and synthetic resins fabrication |
| 37990 | Chemical products industries |
| 39990 | Manufactured products industries |

## TABLE A.37.3-4
## Emission Factors for VOCs from Plastics Production - 1985

| Resin | Process | Resin Processed (kt) | % of Total Resins | E.F. (g/kg resin) | Emissions (tonnes) | Process % for Each Resin |
|---|---|---|---|---|---|---|
| Polystyrene | Foam HCs | 27.0 | | 50.0 | 1350 | 14 |
| | Foam CFCs | 28.0 | | 0.0 | 0 | 15 |
| | Injection mould | 135.0 | 9.5 | 1.0 | 135 | 71 |
| | | | | | | 100 |
| Polyester | Lamination/therm | 12.2 | | 82.0 | 1000 | 24 |
| | Lamination/bats | 39.0 | 2.6 | 40.5 | 1580 | 76 |
| | | | | | | 100 |
| Polyethylene | Film Extrusion | 185.0 | | 1.5 | 278 | 27 |
| | Moulding | 503.0 | 34.4 | 1.0 | 503 | 73 |
| | | | | | | 100 |
| PVC | Extrusion/ Injection moulding | 327.0 | 16.4 | 5.0 | 1635 | 100 |
| Polypropylene | Film Extrusion | 74.5 | | 1.5 | 112 | 50 |
| | Injection mould | 74.5 | 7.5 | 1.0 | 75 | 50 |
| | | | | | | 100 |
| ABS | Extrusion/mould | 52.0 | 2.6 | 1.0 | 52 | 100 |
| Acetal | Moulding | 2.0 | 0.1 | 1.0 | 2 | 100 |
| Acrylic | Coatings | 26.0 | 1.3 | 20.0 | 520 | 100 |
| Epoxy | Coatings | 12.0 | | 25.0 | 300 | 80 |
| | Laminates | 3.0 | 0.8 | 25.0 | 75 | 20 |
| | | | | | | 100 |

## TABLE A.37.3-4 (Contd.)
## Emission Factors for VOCs from Plastics Production - 1985

| Resin | Process | Resin Processed (kt) | % of Total Resins | E.F. (g/kg resin) | Emissions (tonnes) | Process % for Each Resin |
|---|---|---|---|---|---|---|
| Phenol | Adhesives | 28.0 | | 25.0 | 700 | 50 |
| formaldehyde | Moulding | 17.0 | | 33.5 | 570 | 30 |
| | Foams | 11.0 | 2.8 | 0.0 | 0 | 20 |
| | | | | | | 100 |
| Polyamide | Moulded | 15.0 | | 20.0 | 300 | 17 |
| | Extruded | 74.0 | 4.5 | 5.0 | 370 | 83 |
| | | | | | | 100 |
| Polycarbonate | Moulded | 9.0 | 0.5 | 32.0 | 288 | 100 |
| Polyesters (Thermoplastic) | | 70.0 | 3.5 | 1.0 | 70 | 100 |
| Polyphenylene | Injection mould | 3.0 | 0.2 | 20.0 | 60 | 100 |
| Polyurethane | Flex. foam | 33.6 | | 0.0 | 0 | 30 |
| | Rigid foam | 76.0 | | 1.0 | 76 | 68 |
| | Thermoplastic | 2.4 | 5.6 | 46.0 | 110 | 2 |
| | | | | | | 100 |
| Urea | Adhesives | 98.0 | | 25.0 | 2450 | 75 |
| formaldehyde | Moulding | 33.0 | 6.6 | 20.0 | 660 | 25 |
| | | | | | | 100 |
| Other | Moulding | 21.0 | 1.1 | 20.0 | 420 | 100 |
| **Totals** | | **1991.2** | **100.0** | | **13,691** | |

Based on CCME (1990)

## TABLE A.37.3-5

## Comparison of the Distribution of Resin Processes (U.S. vs. Canada)

| Operation | U.S. (1978)<br>% | Canada 1985<br>(Table A.37.4-4)<br>% |
|---|---|---|
| Adhesives | 5.7 | 6.3 |
| Coating | 4.4 | 1.9 |
| Extrusion | 23.6 | 39.5 |
| Film and Sheet | 20.5 | |
| Foam | 8.9 | 8.8 |
| Laminates | 0.6 | 2.7 |
| Moulding | 36.3 | 40.8 |
| | 100.0 | 100.0 |

## References - Section A.37.3

Canadian Council of Ministers of the Environment (CCME) 1990(a). "Control Technologies for Management of Nitrogen Oxides ($NO_x$) and Volatile Organic Compounds (VOC) in Canada; Work Sub-Group 6.4. Products Substitution and Miscellaneous Sources - VOC". Report prepared by Public Consultation Multistakeholder Work Sub-Groups on $NO_x$/VOC Control Technologies.

Edwards, W.C. and T. Cotton, 1988, "VOC Emissions Methods Manual". Report prepared for Environment Canada by B.H. Levelton and Associates.

MEP Company and Ontario Research Foundation (MEP/ORF 1985). "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Report prepared for Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory". Report prepared by Radian Corp. NTIS PB87-198735.

## A.37.4 ORGANIC CHEMICAL INDUSTRY (SIC 37120)

### a) General Description

This sector encompasses a large number of different product industries and the raw materials, processes used and products produced are in most cases unique to individual plants. Volatile organic hydrocarbons (VOC) are the significant pollutants emitted by this sector. In addition, the other common air pollutants, $SO_X$, $NO_X$, CO and TSP are emitted by fuel combustion in the generation of process stream or in process heaters.

In 1985, there were 78 plants in Canada, operating 183 individual production units, producing 58 different chemical products as listed in Table A.37.4-1. The twenty largest emitters of VOC by rank, as estimated by Edwards and Wilkin (1988), are provided in Table A.37.4-2 and account for approximately 95% of the total sector emissions. Brief descriptions of the production processes for thirty of the 58 products produced in Canada have been extracted from Edwards and Wilkin (1988) and are provided in Section b), below. The VOC emissions associated with these thirty products are estimated to account for 98% of the sector total.

### b) Process Description

The Canadian organic chemical and petrochemical industries use raw materials which are primarily derived from natural gas and crude oil. These raw materials (which include methanol, ethylene, propylene, butadiene and butylenes, benzene, toluene and xylenes) are converted into intermediates and derivatives by means of one or more chemical processes (Edwards and Wilkin 1988).

The emission sources and emission factors for the processes and chemicals included in this sector are listed in U.S. EPA (1987) and generally fall into the following categories:

Process Emissions (SCC 3-01-XXX-XX):
The sources of process emissions will be dependant on the unit processes used in the production of the final product. Examples of these processes are distillation, adsorption, absorption, reaction, crystallization and liquid/liquid extraction. The unit processes typically used in the production of the thirty products accounting for an estimated 98% of the Canadian VOC emissions can be found in the flow schematics provided in Edwards and Wilkin (1988). Some of these processes may be carried out under pressure or vacuum, and under elevated or below ambient temperature. Emissions in this category are from well defined process exit streams.

Fugitive Emissions (SCC 3-01-XXX-XX):
These emissions are defined as those due to leakage at pump seals, valve stems, compressors, sampling connections, pressure relief seals, flanges and open-ended lines.

Materials Handling and Withdrawal Emissions (SCC 4-07-XXX-XX):
These emissions are mostly associated with filling and unloading of feedstock, intermediate product and end-product storage vessels whereby the vapour space in these vessels is decreased in volume.

Storage Emissions (SCC 4-07-XXX-XX):
These are emitted by static material held in feedstock, intermediate product or end-product storage vessels (breathing losses).

The following descriptions have been extracted from more detailed information provided by Edwards and Wilkin (1988). In view of the diversity of the processes and operations involved in the production of the various products listed in Table A.37.4-1, an extensive list of Source Classification Codes is required to ensure that all plant emission sources are included for each SIC.

Acetic Acid (SCC 3-01-132-XX):
Acetic acid is produced by the continuous, liquid-phase, catalyzed reaction between methanol and carbon monoxide. The acetic acid is purified by distillation, and the various gaseous vents are scrubbed to recover volatile organic compounds before being finally vented, usually to a flare.

Acrylonitrile Butadiene Styrene Resin (ABS) (SCC 3-01-018-49):
The manufacture of ABS involves the initial emulsion polymerization of butadiene to produce polybutadiene. After removal of unreacted butadiene by vaporization, the polybutadiene latex is reacted with styrene and acrylonitrile to produce ABS, which is then aged, filtered, washed and dried.

Adipic Acid (SCC 3-01-001-XX):
Adipic acid is produced by the two-stage oxidation of cyclohexane. In the first step, cyclohexane is air oxidized to a mixture of cyclohexanone and cyclohexanol, followed by the oxidation of this mixture by nitric acid to produce adipic acid. The majority of VOC emissions will occur in the first oxidation step.

Benzene, Toluene and Xylenes (BTX) (SCC-3-01-258-XX):
Benzene, toluene and xylenes are primarily recovered from a fraction of crude oil boiling in the 65-175°C range. The aromatic content of this fraction is often enhanced by means of reforming before processing in the BTX unit. A selective solvent is used to extract the aromatics before purification of the benzene, toluene and xylenes by distillation. The separation of para-xylene from the other xylenes is achieved by crystallization or selective adsorption, and the amount of p-xylene recovered is increased by isomerization of the other xylenes. The complexity of a BTX unit can be reduced so as to only recover one or two of the aromatic components. Benzene can also be recovered as a byproduct of ethylene production.

n-Butyraldehyde (SCC 3-01-120-21):
n-Butyraldehyde is produced by the continuous, liquid-phase, catalyzed reaction between methanol and carbon monoxide. The acetic acid is

purified by distillation, and the various gaseous vents are scrubbed to recover volatile organic compounds before being finally vented, usually to a flare.

Cellulose Acetate (SCC 3-01-025-XX):
Cellulose acetate is produced from cellulose and acetic anhydride. The cellulose is first activated, then converted to a cellulose triacetate using a catalyst such as sulphuric acid in a solvent such as acetic acid. The triacetate is then hydrolyzed to the monoacetate in an aqueous solution. Excess acetic acid is recovered by distillation or extraction.

Cumene (SCC 3-01-156-XX):
Cumene is manufactured by the gas-phase heterogeneously catalyzed reaction between benzene and propylene. Typical catalysts include phosphoric acid impregnated on Kieselguhr. Cumene is purified by distillation, with recycle of excess benzene and polypropylated product.

Cyclohexane (SCC 3-01-157-XX):
Cyclohexane is produced by the hydrogenation of benzene using a solid catalyst either in suspension in reactor liquid or in a gas/solid heterogeneous reactor. Excess hydrogen can be recycled or used as a fuel.

Ethyl Benzene (SCC 3-01-169-XX):
Ethyl benzene is typically produced by the alkylation of benzene with ethylene using a liquid phase catalyst such as aluminum chloride. Separation of benzene and polyethylbenzenes for recycle, as well as purification of the ethyl benzene, are achieved in a distillation train.

Ethylene (SCC 3-01-197-XX)
Ethylene is produced by the pyrolysis of various hydrocarbon feedstocks at 750-900°C using residence times of less than 0.1 second to 0.6 second. The yield to ethylene and the amounts of the various byproducts depends markedly on the nature of the feed hydrocarbon, with ethane giving high ethylene yields and relatively small amounts of byproducts, and gas oil

giving decreased ethylene yield but major amounts of propylene, butadiene, butylenes and other components. Separation is by means of a complex series of distillations and purification steps.

Ethylene Dichloride and Vinyl Chloride (SCC 3-01-125-XX):
Ethylene dichloride is produced from ethylene either by direct, liquid phase chlorination using chlorine, or by gaseous oxychlorination using hydrogen chloride and oxygen over a solid copper based catalyst. High temperature cracking of the ethylene dichloride produces vinyl chloride plus hydrogen chloride. This hydrogen chloride can be recycled to the ethylene oxychlorination reactor and thus make possible a "balanced" ethylene dichloride and vinyl chloride process based upon feedstocks of ethylene, chlorine and oxygen, with no net production of hydrogen chloride. Purification of ethylene dichloride and vinyl chloride is achieved by distillation.

Ethylene Oxide (SCC 3-01-174-XX):
Ethylene oxide is produced by the direct, partial oxidation of ethylene by oxygen in a gas phase reaction catalyzed by a supported silver catalyst. Separation and purification of the ethylene oxide is achieved by absorption in water, desorption and finally distillation.

Ethylene Glycol (SCC 3-01-251-XX):
Ethylene glycol is produced by the reaction of ethylene oxide with high temperature water under pressure. Excess water is removed in a multiple stage evaporator and ethylene glycol (and higher glycols) purified by distillation.

Formaldehyde (SCC 3-01-120-XX):
Formaldehyde is produced by the reaction of methanol and oxygen at atmospheric pressure over either a silver catalyst at 600 to 650°C, or a metal oxide catalyst at 300 to 400°C. The reaction gases are contacted with water to produce a solution containing as much as 55% formaldehyde and 1% methanol.

Methanol (SCC 3-01-250-XX):
Methanol is produced by the reaction of synthesis gas (hydrogen, carbon monoxide and carbon dioxide) over either a high pressure zinc oxide-chromium oxide or a low pressure copper-zinc oxide catalyst. Recently built production plants use the low pressure process, and typically produce synthesis gas by reforming natural gas. Purging of light components and purification of the methanol is achieved in distillation units.

Phenol and Acetone (SCC 30-1-202-XX and SCC 3-01-091-XX):
Phenol and acetone are co-produced in a process which involves the air oxidation of cumene hydroperoxide, followed by the acid catalyzed cleavage of the hydroperoxide to acetone and phenol. Phenol and acetone are purified in successive distillation steps.

Phenol Formaldehyde and Urea Formaldehyde Resins (SCC 3-01-018-XX):
Phenol formaldehyde and urea formaldehyde resins are both produced in batch (non-continuous) operations using similar equipment and procedures. Typical processing involves charging a reactor kettle with the desired amounts of aqueous formaldehyde and phenol or urea. Catalyst is added and the reaction mixture maintained at an elevated temperature for a specific period of time. Water and excess reagents are removed by heating under vacuum and the resin is then discharged for shipping or further processing.

Polyethylene: High Density (HDPE), Low Density (LDPE) and Linear Low Density (LLPE) (SCC 3-01-018-XX):
There are two methods of polymerizing ethylene to produce polyethylene: a high pressure process which can produce only low density polyethylene; and a low pressure process which can give low density, linear low density and high density polyethylene. The properties of the polymer produced depend, among other things, upon the amount and nature of other monomers added to the reactor. After removing unreacted ethylene for recycle as well as any reaction solvent, additives such as stabilizers are introduced and the polyethylene can then be converted (for example, by melt extrusion) into a form suitable for sale.

Polyvinylchloride (SCC 3-01-018-XX):
Polyvinylchloride is produced from vinyl chloride by either suspension (major process) or mass polymerization. The initial reaction product is processed to remove residual monomer for recycle followed, in the case of suspension polymerization, by drying of the polymer product. The polymer is then screened/classified and sent to storage until shipment.

Propylene Oxide (SCC 3-01-205-XX):
Propylene oxide is produced by either the chlorohydrin or the hydroperoxide process. Canadian propylene oxide production uses the chlorohydrin process, which involves the reaction of propylene with chlorine and water to produce propylene chlorohydrin, followed by dehydrochlorination with caustic to give propylene oxide and salt. Propylene oxide is purified by distillation.

Styrene (SCC 3-01-206-XX):
Styrene is produced by the dehydrogenation of ethyl benzene in the vapour phase, catalyzed by a heterogeneous catalyst based upon ferric oxide. Removal of byproducts, separation of unreacted ethyl benzene for recycle and purification of ethylbenzene are achieved in a series of distillation columns.

Vinyl Acetate (SCC-3-01-167-XX):
Vinyl acetate is produced by the heterogeneously catalyzed gas phase reaction between ethylene, acetic acid vapour and oxygen. Vinyl acetate is condensed from the reaction gas and then purified by distillation. Excess ethylene is recycled to the reactor with removal of byproduct carbon dioxide in an absorption/stripping operation.

## c) Inventory Approach

A VOC emission inventory for the organic chemical industry sector will usually involve point source methodology applied to the processes on each plant site. In view of the large number of different processes and products covered by this sector, emission factors are generally based on limited data and factors determined for one plant may be inappropriate for another due to differences in the processing and operating conditions.

The U.S. EPA has published a series of documents on locating and estimating air emissions from industrial sources of a variety of organic chemicals. These documents are useful for obtaining information about (i) the types of sources that may emit the chemical, (ii) process variations and release points that may be expected within these sources, and (iii) available emissions information indicating the potential for release of the chemical to the air from each operation (U.E. EPA 1984). Source test procedures are also included in this series of documents. The user of these documents is cautioned in the documents against using the quantitative emissions information to develop an exact assessment of emissions for any particular facility. The information is based on insufficient data and no estimate of the error can be made if factors are used to calculate emissions for any given facility. In extreme cases, the error could range to orders-of-magnitude.

Based on a 1985 VOC inventory for this sector, 52% of the emissions are from the processes, while the fugitive and storage/loading/spills emissions are estimated to be 42% and 6%, respectively (Edwards and Wilkin 1988). Hence, it is clear that equal emphasis in the inventory preparation should be directed towards obtaining accurate process and fugitive emissions estimates. Reliable process emissions are best obtained from plant specific data.

### d) Preferred Emission Estimation Procedure

Plant specific data should be obtained from each producer through questionnaire or direct plant contacts. Through such contact, the following data and information should be assembled:

- Discharge Permit and Process Flowsheet
- source test reports

- annual consumption/production data
- intermediate products and end products
- storage vessel throughputs and capacities
- annual operating data and usage

These data are most important for proper estimates of process emissions. A survey of VOC emissions from selected chemical plants has been carried out for 1988, and the results of this study can be used to derive emission factors (Kosteltz 1990).

While the best data will be obtained directly from the plant, its availability may be limited due to practical or proprietary restrictions. Table A.37.4-3 lists alternate sources from which the required data may be obtained directly or calculated from other information. The Federal and Provincial Environment Ministries should have emission test data reports or studies to support the permit application and demonstrate compliance with permit guidelines. Such data may also include information on consumption and production of materials. In addition, the discharge permit itself should identify operating period and duration, vessel capacities and material characteristics (Edwards and Cotton 1988).

Information for specific plants is also available from the private sector (Corpus 1986, and Canadian Chemical Producers Association 1987) and may be used to determine annual consumption/production rates and operating period. Where total national production figures are given, individual process productions can be estimated based on individual capacity fractions of the aggregate product capacity (Edwards and Cotton 1988).

The data and information collection procedures should focus mainly on the process emissions. Data for estimating working and storage losses through the application of emission factors, will generally also be readily available.

Process Emissions (Edwards and Cotton 1988)

VOC emissions discharged from process sources should be determined from emissions test data where these data exist. Using this data, an average annual emission factor can be calculated. If the factor basis is per unit production, the appropriate annual production is used to calculate the annual VOC emission:

$$E_p = F_p \times P$$

where,

$E_p$ = VOC emission for the process source
$F_p$ = Process emission factor - production basis
$P$ = Annual process production

It is important that the process production used in this calculation corresponds to the production basis of the calculated emission factor. For example, if emission test data report the output rate of an intermediate product produced by the unit source, the annual process production used will be for the intermediate product, not the end-product. In addition, care must be taken when multiple-sources of identical nature operate in parallel process lines. The production value should be apportioned relative to the process flow through each of the lines.

If the factor basis, as calculated from emissions test data is per unit time, the annual VOC emission is determined using annual operating time as:

$$E_p = F_p \times H$$

where,

$E_p$ = VOC emission for the process source
$F_t$ = Process emission factor - time basis
$H$ = Annual process duration

When using the time-based emission factor it is necessary to ascertain that the process characteristics during the emission test are representative of the annual operation. This can be accomplished by comparing characteristic production parameters during the test to typical values.

Working Losses (Edwards and Cotton 1988):
Emissions of VOC arising from handling of materials in storage vessels are calculated using published emission factors for the specific chemical. These factors are tabulated within the NAPAP Emission Factors listing given in U.S. EPA (1987). The appropriate emission factor used for this calculation is designated as the working or withdrawal emission in this listing. This factor is used in conjunction with the vessel throughput to calculate the annual VOC emission as:

$$E_h = F_h \times T$$

where,

$E_h$ = Working loss emission
$F_h$ = NAPAP working or withdrawal emission factor
$T$ = Annual vessel throughput

The throughput used in this calculation refers to the annual flow of material stored within the vessel. If it can be demonstrated that the net change of stored material volume over the year is negligible compared to the consumption/production of the feedstock/product, then the consumption/ production value may be used as throughput. Where multiple storage vessels are used in parallel for a given process and individual vessel throughputs are unavailable, each must be determined by apportioning the total on the basis of unloading/filling frequency and duration data or vessel capacity.

Storage Losses (Edwards and Cotton 1988):
Emissions of VOC arising from static losses of material stored in holding vessels are calculated using published emission factors for the specific material. These factors are tabulated within the NAPAP Emission Factors listing under SCC 4-07-XXX-XX U.S. EPA (1987). The appropriate emission factor used for this calculation is designated as the standing or breathing emission and is used in conjunction with the volumetric capacity of the given storage vessel using the formula:

$$E_s = F_s \times V$$

where,

$E_s$ = Annual storage emission
$F_s$ = NAPAP breathing or standing emission factor
$T$ = Storage vessel volumetric capacity

When calculating this annual VOC emission it should be determined if the storage vessel in question was taken out of service or empty for a significant period of time and, if so, the annual emission should be appropriately adjusted. For example, if the vessel was out of service for three months during the year, the calculated annual emission could be adjusted by a 25% reduction.

Fugitive Emissions:

Fugitive emissions are estimated using leakage emission factors which are based on actual numbers of pumps, valves, flanges, etc., rather than plant throughput. The number of leak sources can be determined from detailed flow sheets and such count information should be requested.

There are five methods of determining emissions to the air of volatile compounds from equipment component leaks (Kosteltz 1990, U.S. EPA 1988). They are: 1) Average SOCMI Emission Factor Method; 2) Leak/No Leak Emission Factor Method; 3) Stratified Emission Factor Method; and 4) Leak Rate/ Screening Value Correlations Method. 5) Unit specific correlations by bagging of equipment. The first method uses an equipment component count by equipment type and an average emission factor per component to calculate emissions. The latter four methods use measured concentrations about each equipment component to determine the appropriate emission factors (Ellis and Lackaye 1989).

The Average SOCMI (Synthetic Organic Chemical Manufacturing Industry) Emission Factor Method involves multiplying the number of equipment components according to type (valves, flanges, etc.) and service (gas, light liquid, heavy liquid) by an appropriate emission factor from EPA's documentation (U.S. EPA 1988).

The Leak/No Leak method involves measuring the air concentration for each equipment component using EPA Method 21. Those for which the concentration is above 10,000 ppm are classed as leakers and those below 10,000 ppm as non-leakers. The average EPA factors are then applied according to the numbers of leakers and non-leakers to provide a total fugitive emission.

For the Stratified Method, the concentrations are grouped into three ranges; 0-1,000 ppm, 1,001-10,000 ppm and over 10,000 ppm. The average EPA emission factors are again applied using a weighting factor for each concentration group to arrive at the total emission.

In method (4), correlations are used to improve upon the results achieved with the stratified approach. Concentration measurements from a survey of plant equipment with a portable analyzer can be used with correlations for valves, flanges and pump seals in a limited number of service categories, developed by the U.S. EPA, to yield improved emission factors compared to the three levels used in the conventional stratified method.

Method (5) yields the most accurate results, but places the highest demand on resources because of the requirement to screen plant equipment with a portable analyzer, and then bag selected equipment to measure the actual leak rate. Correlations must be developed relating the screening concentration to the leak rate found from bagging of components.
Clearly, the level of effort required for implementing the latter three methods is considerable. Ellis and Lackaye (1989) compared the first three methods and found that the Average Emission Factor Method, while relatively easy to implement, yields estimates that are much higher than the Leak/No-Leak or Stratified Methods.

At a minimum, plants should use Method (1) with counts of equipment from process and instrumentation drawings, supplementing this data with field verification as appropriate and when possible. Other fugitive emission calculation methods could be used to improve on the estimate of emission from these sources determined by Method (1).

In an emission survey, emission factors using methods (1), (2) and (3) were used by plant personnel to acquire data (Kosteltz 1990). The emission factors obtained using these methods are provided in Table A.37.4-4.

### e) Activity Level

Once the most reliable emission factor has been developed for each of the components within the process control envelope, the appropriate base quantity can be obtained for each. These will most often be in terms of annual production or product throughput, although sometimes base quantities will be on a time basis (Edwards and Cotton 1988).

The best available source for the base quantity values is directly from the plant contact. Virtually all plants will have the required figures to determine the production rate of a given process. However, on occasion, some data may not be directly available for intermediate production or feed consumption. These may often be estimated based on other operating parameters or mass balances. The more complex the plant facility and individual process, the more difficult it is to obtain all required base quantities (Edwards and Cotton 1988).

In rare instances, sufficient data will be unavailable from the plant to determine reliable base quantity values needed for the inventory. In these cases, other sources should be used to obtain statistical data for aggregate production, which can then be disaggregated using available plant data. Sources of production data include:

- Trade Journals for the industry
- Canadian Chemical Producers Association
- Provincial and Federal Trade and Commerce Ministries
- Statistics Canada
- Process Discharge Permits
- Previous inventories

When determining the base quantity value for the process component, caution must be exercised regardless of whether data is obtained from the plant or elsewhere. The value used must correspond to the unit basis of the emission factor.

## f) Alternative Emission Estimation Procedures

Process Emissions (Edwards and Cotton 1988):
Where VOC emission test data are not available, or is deemed not to be representative of current emissions, a published VOC emission factor can be used for the appropriate chemical and process. These emission factors are tabulated within the NAPAP Emission Factors listing (SCC 3-01-XXX-XX). When using these factors, it is important in many cases to identify the process used for manufacturing the product, as process variations may substantially alter emission rates. These factors are given for uncontrolled emissions and the existence of pollution control devices must be identified. When applicable, the emission factor should be corrected based on VOC removal efficiency of the control device.

Where production/consumption data is not available for the production unit envelope, alternate estimation techniques may be applied. Existing material balance calculations may be available in sufficient detail to calculate the required input/output value. Also process design specifications may be consulted to determine flow of input or output by prorating the specified design rate against measured or known characteristic flows.

Working Losses/Storage Losses (Edwards and Cotton 1988):
Emission factors for standing, breathing and working losses are available in the NAPAP Emission Factor listing for the vast majority of chemicals found in the Canadian petrochemical industry. In rare instances, however, published emission factors may not be available for a given compound. In these cases, emission rates can be estimated by calculations based on the physical characteristics of the material and tank design (American Petroleum Institute 1969, EPA 1985).

The details of storage capacity may be difficult or impractical to obtain and can be approximated based on plant capacity and knowledge of the materials physical characteristics, and proximity of supply or market. As a general basis for estimation it may be assumed that feedstock and product storage capacity for a given process will be in the order of one month of process production. Actual storage capacity may range from one week to three months, depending on material stability, process capacity and proximity of supply/market (i.e., local or world market). Approximations for storage capacity at plants manufacturing organic chemicals have been developed by Edwards and Wilkin (1988).

Fugitive Emissions (Edwards and Cotton 1988):
Obtaining equipment counts to determine fugitive emissions within a production unit envelope may prove to be impractical or beyond budgetry limitations. For some chemical processes fugitive emission factors are estimated in the NAPAP Emission Factors listing under the heading "Fugitive Emissions: General" for each process category. These emission factors are based on average equipment counts for process units included in a study conducted of SOCMI process units (U.S. EPA 1981). Fugitive emission factors for average operations of specific Canadian plants are also available from Environment Canada (Kosteltz 1990).

### g) Temporal Variability

Annual and monthly daily level or base quantity data should be obtained as well as a typical operating cycle on a daily and weekly basis. Since most chemical processes are continuously in operation, only data on scheduled maintenance shut-downs need be collected. Batch processes on the other hand will have emissions which change over the production cycle. If the batch cycle consistently follows a daily schedule, then data on the schedule should be obtained. If, however, batches do not follow a daily pattern, then these processes are treated as continuous and only periods of scheduled maintenance shut-down need be ascertained.

### h) Geographical Variability

The inventory for this sector is done on a point-by-point basis.

## i) Point Source Establishments

The following list of establishments is from a recent VOC emissions survey conducted for Environment Canada (Kosteltz 1990).

Benzene/Toluene/Xylene
- Carbochem, Hamilton, Ontario
- Esso Chemical, Sarnia, Ontario
- Sunoco, Sarnia, Ontario

Ethylene
- Esso Chemical, Sarnia, Ontario
- Nova (Ethylene I Plant), Joffre, Alberta
- Nova (Ethylene II Plant), Joffre, Alberta
- Petromont, Varennes, Quebec

Ethylene Oxide/Ethylene Glycol
- Dow, Fort Saskatchewan, Alberta
- Union Carbide, Montreal, Quebec
- Union Carbide, Prentiss, Alberta

Polyethylene
- Dow, Fort Saskatchewan, Alberta (linear low density)
- Dow, Sarnia, Ontario (low density)
- Dow, Sarnia, Ontario (high density)
- Dupont, Corunna, Ontario (linear low density)
- Esso Chemical, Sarnia, Ontario (linear low density)
- Nova, Joffre, Alberta (linear low density)
- Novacor, Moore, Ontario (high density and low density)

Maleic Anhydride
- Monsanto, LaSalle, Quebec

Styrene/Ethylbenzene
- Dow, Sarnia, Ontario
- Polysar, Sarnia, Ontario
- Shell, Scotford, Alberta

# TABLE A.37.4-1

## VOC Emissions by Chemical Product in Alphabetical Order (Edwards and Wilkin 1988)

| Chemical Product | Number of Production Units |
|---|---|
| Acetic Acid | 1 |
| Acetone | 2 |
| Acetylene | 1 |
| Acrylonitrile-Butadiene-Styrene | 2 |
| Adipic Acid | 1 |
| Benzene | 10 |
| n-Butyraldehyde | 1 |
| Butadiene | 4 |
| Butylenes | 6 |
| Butyl Rubber | 1 |
| Benzoic Acid | 1 |
| Cellulose Acetate | 1 |
| Cumene | 1 |
| Cyclohexane | 1 |
| Dodecene | 1 |
| Ethylene Dichloride | 2 |
| Ethylene Glycols | 3 |
| Ethylene Oxide | 3 |
| Epoxy Resins | 1 |
| Ethanolamines | 2 |
| Ethyl Benzene | 3 |
| Ethylene | 4 |
| 2-Ethyl Hexanol | 1 |
| Ethoxylated Alcohols | 4 |
| Ethyl Alcohol | 1 |
| Formaldehyde | 11 |
| Hexamethylene Diamine | 1 |
| Hexamethylene Tetramine | 1 |
| Iso-propyl Alcohol | 1 |
| Methanol | 3 |
| Nonene | 2 |
| Nonyl Phenol | 3 |

## TABLE A.37.4-1 (Contd.)

## VOC Emissions by Chemical Product in Alphabetical Order (Edwards and Wilkin 1988)

| Chemical Product | Number of Production Units |
|---|---|
| Polybutadiene | 1 |
| Polyethylene - high density | 3 |
| Polyethylene - low density | 4 |
| Polyethylene - linear low density | 3 |
| Pentaerythitol | 1 |
| Polyetherpolyols | 3 |
| Polyethylene Terephthallate | 1 |
| Propylene Glycols | 1 |
| Phthallic Anhydride | 1 |
| Phenol Formaldehyde Resin | 18 |
| Phenol | 2 |
| Propylene Oxide | 1 |
| Polystyrene | 6 |
| Polypropylene | 2 |
| Propylene | 10 |
| Polyvinyl Chloride | 4 |
| Styrene Butadiene Latex | 3 |
| Styrene Butadiene Rubber | 1 |
| Styrene | 3 |
| Tetraethyl Lead | 2 |
| Toluene | 8 |
| Urea Formaldehyde Resin | 12 |
| Vinyl Acetate | 1 |
| Vinyl Chloride | 2 |
| Xylenes | 7 |
| **Total** | 183 |

## TABLE A.37.4-2

## Twenty Largest Emissions by Chemical Product (Edwards and Wilkin 1988)

| Rank | Chemical Product | Number of Production Units |
|---|---|---|
| 1 | Polyethylene - low density | 4 |
| 2 | Ethylene | 4 |
| 3 | Styrene | 3 |
| 4 | n-Butyraldehyde | 1 |
| 5 | Polyethylene - linear low density | 3 |
| 6 | Polyethylene - high density | 3 |
| 7 | Ethylene Oxide | 3 |
| 8 | Cellulose Acetate | 1 |
| 9 | Methanol | 3 |
| 10 | Butyl Rubber | 1 |
| 11 | Adipic Acid | 1 |
| 12 | Ethylene Dichloride | 2 |
| 13 | Vinyl Chloride | 2 |
| 14 | Polyvinyl Chloride | 4 |
| 15 | Benzene | 10 |
| 16 | Formaldehyde | 11 |
| 17 | Acrylonitrile Butadiene Styrene | 2 |
| 18 | Polystyrene | 6 |
| 19 | Phenol | 2 |
| 10 | Urea Formaldehyde | 12 |
|  | **Total** | 78 |

## TABLE A.37.4-3

## Data Procurement Source

| Emission Source Characteristic | Data | Primary Source | Secondary Sources |
|---|---|---|---|
| (a) Process Emission | Source Test Data (VOC concentration, discharge rate, production rate, sample method) | Plant Contact | •Provincial Ministry of Environment<br>•Environment Canada |
| | Annual Consumption/ Production | Plant Contact | •Provincial Ministry of Environment<br>•Environment Canada<br>•Statistics Canada<br>•Corpus Information Services<br>*Canadian Chem.Producers Assoc. |
| | Annual Operating | Plant Contact | •Permit data |
| (b) Working Losses | Emission Factor | NAPAP | |
| | Throughput | Plant Contact | •Determined from consumption/ production |
| | Working period/ duration | Plant Contact | •Permit data |
| | Vessel Capacity | Plant Contact | •Permit data |
| (c) Storage Losses | Emission Factor | NAPAP | |
| | Vessel Capacity and material | Plant Contact | •Permit data |
| | Annual Vessel Usage | Plant Contact | •Permit data |
| (d) Fugitive Emissions | Equipment Component Count | Plant Contact | |
| | Emission Factor | SOCMI | •NAPAP<br>•U.S. EPA 1988 |
| | Annual Operating Hours | Plant Contact | •Permit data |

(Edwards and Cotton, 1988)

## TABLE A.37.4-4

## Fugitive Emission Sources and Alternate Emission Factors

| Equipment | Service[a] | Average SOCMI kg/source/h | Leak - No-Leak kg/source/h | | Stratified Screening Values, ppmv kg/source/h | | |
|---|---|---|---|---|---|---|---|
| | | | Leaking[b] | Non-leaking[b] | 0-1,000 | 1,001-10,000 | >10,000 |
| Valves | Gas/vapour | 0.0056 | 0.0451 | 0.00048 | 0.00014 | 0.00165 | 0.0451 |
| | Light liquid | 0.0071 | 0.0852 | 0.00171 | 0.00028 | 0.00963 | 0.0852 |
| | Heavy liquid | 0.00023 | 0.00023 | 0.00023 | 0.00023 | 0.00023 | 0.00023 |
| Pump Seals | Light liquid | 0.0494 | 0.437 | 0.0120 | 0.00198 | 0.0335 | 0.437 |
| | Heavy liquid | 0.0214 | 0.3885 | 0.0135 | 0.00380 | 0.0926 | 0.3885 |
| Compressor Seals | Gas/vapour | 0.228 | 1.608 | 0.0894 | 0.01132 | 0.264 | 1.608 |
| Pressure Relief Valve | Gas/vapour | 0.104 | 1.691 | 0.0447 | 0.0114 | 0.279 | 1.691 |
| Flanges | All | 0.00083 | 0.0375 | 0.00006 | 0.00002 | 0.00875 | 0.0375 |
| Open-ended Lines | All | 0.0017 | 0.01195 | 0.00150 | 0.00013 | 0.00876 | 0.01195 |
| Sampling Connections | All | 0.0150 | Same as SOCMI | | Same as SOCMI | | |

[a] Definitions of service types are included in the "Background and Instructions" section of the questionnaire (Appendix B)

[b] Leaking - >0,000 ppm concentration; Non-leaking - <10,000 ppm concentration; based on screening survey

Source: CMA, 1989

## References - Section A.37.4

American Petroleum Institute, 1969, "Petrochemical Evaporation Loss from Storage Tanks", API Bulletin 2523.

Canadian Chemical Producers Association, 1987. "Overview of the Canadian Chemical Manufacturing Industry".

CMA, 1989, "Improving Air Quality: Guidance for Estimating Fugitive Emissions from Equipment", Chemical Manufacturers Association, Washington, D.C., January.

Corpus Information Services, 1986, "The Canadian Chemical Industry".

Edwards, W.C. and T. Cotton, 1988, "VOC Emissions Methods Manual". Report prepared for Environment Canada by B.H. Levelton and Associates.

Edwards, W.C. and J.G. Wilkin, 1988, "VOC Emissions Inventory for the Organic Chemical Industry in Canada". Report prepared by B.H. Levelton and Associates.

Ellins, H.M. and R. Lackaye, 1989, "Estimating Fugitive Emissions of Volatile Compounds from Equipment Leaks". J. of the Air Poll. Control Assoc., 39(12), p.1619-1622.

Kosteltz, A. (Private Communication 1990), "Emissions of Volatile Organic Compounds from Selected Chemical Plants", Draft report prepared by B.H. Levelton and Associates for Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1981, "Frequency of Leak Occurrence for Fittings in Synthetic Organic Chemical Plant Process Units", EPA 600/2-81-003.

U.S. Environmental Protection Agency (U.S. EPA), 1984. Office of Air Quality Planning and Standards, Report Series EPA-450/4-84-007.

U.S. Environmental Protection Agency (U.S. EPA), 1985. Compilation of Air Pollutant Emission Factors: Volume 1 - Stationary Point and Area Sources; Volume 2 - Mobile Sources (4th Edition)", Report AP-42 (NTIS PB86-124906/AS and PB87-205266).

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory. Report prepared by Radian Corp. NTIS PB87-198735.

U.S. Environmental Protection Agency (U.S. EPA), 1988. "Protocols for Generating Unit - Specific Emission Estimates for Equipment Leaks of VOC and VHAP", Report EPA-450/3-88-010.

## A.37.5 NITRIC ACID PRODUCTION (SIC 37114)

### a) General Description

The ammonia oxidation process is the principal method of producing nitric acid in Canada. It involves the high-temperature oxidation of ammonia with air in the presence of a platinum catalyst to form nitric oxide. After cooling, additional air is required to complete the oxidation to nitrogen dioxide. The product is absorbed with water to form a weak nitric acid, which can be consumed or further concentrated by treating it with strong sulphuric acid (Environment Canada 1983).

Nitrogen oxides are the major emissions associated with this process. Minor emissions of hydrocarbons are associated with emission control equipment.

### b) Process Description

The following emission sources are identified with this process:

Weak Acid Plant Tail Gas (SCC 3-01-013-01/-02):
This is the vent stream leaving the nitrogen dioxide absorber after passing through a mist separator. In pre-1970 plant this emission stream was largely uncontrolled. Post-1970 plant have emission control equipment to reduce the $NO_2$ to nitrogen. The catalytic process commonly used consumes natural gas or other fuels.

Nitric Acid Concentrator (SCC 3-01-013-03/-04):
The weak acid produced in the absorber is dehydrated using strong sulphuric acid in a packed column. The acid gas leaving the top of the column is condensed. Gases leaving the condenser are scrubbed and vented to the atmosphere.

Nitric Acid Storage (SCC 3-01-870-05):
Breathing losses from storage in fixed roof tanks, are a minor emission source of nitric acid.

## c) Inventory Approach

Nitric acid plant emissions are prepared using Point Source Methods. All nitrogen oxides should be reported in terms of an equivalent amount of nitrogen dioxide.

## d) Preferred Emission Estimation Procedure

Emission factors for the weak and strong acid processes are provided in:

- AP-42 Emission Factors (U.S. EPA 1985)
- NAPAP Inventory Emission Factors (U.S. EPA 1987)
- questionnaire data reported by Environment Canada (Environment Canada 1983)

Direct contact should be made with producers to establish the age of the plant, process and control equipment used and to obtain plant test data which may be available. Production data may also be provided by the producers.

## e) Activity Level

Base quantity (or production data) which are required in order to apply the emission factors in d) are obtainable from Corpus Information Services CPI Product Profile. Provincial Ministries of the Environment should also be contacted for specific plant production and emissions data.

## f) Alternative Emission Estimation Procedures

If an emissions estimate of lesser accuracy is sufficient for the intended use of the result, then an estimate can be made based on published production quantities or rated plant capacities assuming a percentage of capacity operation. The emission factors in d) should be used.

## g) Temporal Variability

Nitric acid plants operate continuously other than for scheduled shutdowns. If warranted, periods during which the plant was not operating could be determined by contact with the producers.

## h) Geographic Variability

Point source list provides the geographical distribution of nitric acid plants.

## i) Point Source Establishments

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240055 | C-I-L Inc. | McMasterville |
| Manitoba | 460010 | Simplot Chemical Co. Ltd. | |
| Alberta | 480134 | Canadian Industrial Ltd. | Carseland |
| | 480014 | Cominco Ltd., Fertilizer Op. | Calgary |
| | 480013 | Esso Chemical Ltd. | Edmonton |
| | 480012 | Western Co-op Fertilizers Ltd. | Calgary |
| | 480011 | Western Co-op Ltd. | |

## References - Section A.37.5

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Prepared by Environmental Protection Programs Directorate, Report EPA 3-EP-83-10.

U.S. Environmental Protection Agency (U.S. EPA) 1985. "Compilation of Air Pollutant Emission Factors - AP-42".

U.S. Environmental Protection Agency (U.S. EPA) 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory. Report prepared by Radian Corp., NTIS PB 87-198735.

# A.37.6 NITRATE FERTILIZER PRODUCTION

Ammonium Nitrate (SIC 37210):
Urea (SIC 37220):

## a) General Description

This sector comprises ammonium nitrate and urea production. Ammonium nitrate is produced by neutralizing nitric acid with ammonia to produce a concentrated solution of the ammonium nitrate salt. This solution is further concentrated by evaporation. The concentrated melt is sprayed into a prilling tower or rotary granulator. Depending on the residual water in the melt, either high or low density granules are produced.

Urea is produced under high pressure through the reaction of liquid ammonia and liquid carbon dioxide. Granules are produced in a prilling tower or rotary granulator.

The main emissions from these processes are ammonia, particulate and VOC. In addition, nitrogen oxides are emitted from the ammonium nitrate process. (U.S. EPA 1985)

## b) Process Description

Ammonium Nitrate: The following processes are important emission sources:

Neutralizer (SCC 30-1-027-04):
Both ammonia and nitrogen oxides are emitted by this process step.

Solids Formation (SCC 30-1-027-02/-07/-08/-12/-22):
These SCCs cover prilling towers, pan and drum granulators which are sources of particulate and ammonia emissions.

Coolers and Dryers (SCC 3-01-027-03/-14/-25):
These operations are carried out in rotary drums or fluidized beds, during which particulates and ammonia are emitted.

Urea: The following processes are important emission sources:

Solution Concentration (SCC 3-01-040-02):
Operation includes the reactor and concentration of product to produce a melt. Emissions are vented uncontrolled.

Solids Formation (SCC 3-01-040-03/-04/-08/-09/-10/-11):
Granules are formed in a prilling tower or a rotary granulator (drum or pan). The prilling operation may be a fluidized bed operation which also cools the product or non-fluidized bed operation which is followed by some supplementary cooling (SCC 3-01-040-12). Both the solids formation and cooling processes are sources of ammonia and particulate emissions. Emission control may be achieved by wet scrubbing or wet or dry cyclones. (U.S. EPA 1985)

## c) Inventory Approach

Emissions from processes producing ammonium nitrate and urea are compiled using Point Source methodology using emission factor estimates.

## d) Preferred Emission Estimation Procedure

Emission factors for ammonia and nitric acid are provided by AP-42 (U.S. EPA 1985), NAPAP emission factors (U.S. EPA 1987), as well as emission factors available from Environment Canada (Environment Canada 1983). In order to select the appropriate factors, it is necessary to determine the specific processes used and emission control devices which are in place for each plant. This information is best obtain directly from the producer, although such information may also be available from Environment Canada or Provincial Environment Ministries.

## e) Activity Level

Ammonium nitrate and urea production figures may be available in Statistics Canada 46-002, 46-219 and 46-220. The preferred method of obtaining production data is through contact with the producers. Alternative sources of production data are the provincial Ministries of the Environment. Since emissions from this sector are inventoried using point source methodology, data for individual establishments must be obtained.

## f) Alternative Emissions Estimates Procedure

None.

## g) Temporal Variability

The operating schedules for producing these products should be determined through industry contact on a plant-by-plant basis. Generally, operation is steady and continuous for extended periods. Periods when the plants are shut down for scheduled maintenance should also be ascertained.

## h) Geographical Variability

The point source locations provide the geographical distribution of emissions.

## i) Point Source Establishments

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Quebec | 240055 | C-I-L Inc. | McMasterville |
| Ontario | 351010 | Canadian Industries Limited | Courtright |
| Manitoba | 460010 | Simplot Chemical Co. Ltd. | ? |
| Alberta | 480134 | Canadian Industriel Ltd. | Carseland |
|  | 480014 | Cominco Ltd., Fertilizer Op. | Calgary |
|  | 480013 | Esso Chemical Ltd. | Edmonton |
|  | 480012 | Western Co-op Fertilizers | Calgary |
|  | 480011 | Western Co-op Ltd. |  |

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| | 480104 | Canadian Fertilizers Ltd. | Medicine Hat |
| | 480132 | Cominco Ltd. (Carseland Oper.) | Calgary |
| | 480014 | Cominco Ltd., Fertilizer Oper.) | Calgary |
| | 480013 | Esso Chemical Ltd. | Edmonton |
| | 480010 | Sherritt Gordon Mines Ltd. | No Address (need) |

## References - Section A.37.6

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)", Environmental Protection Service Report EPS 3-EP-83-10, pp 181.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors: Volume 1 - Stationary Point and Area Sources; Volume 2 - Mobile Sources (4th Edition)". Report AP-42 (NTIS PB86-124906/AS and PB87-205266).

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Precipitation Assessment Program) Emissions Inventory". Report prepared by Radian Corp. NTIS PB87-198735.

## A.37.7 PHOSPHATE FERTILIZER PRODUCTION (SIC 37115)

### a) General Description

Single superphosphate, triple superphosphate and ammonium phosphates are produced by decomposing phosphate rock with a strong mineral acid. Pre-production phosphate rock processing is inventoried separately under SIC 06290.

Particulate matter is the only criteria pollutant emitted from phosphate fertilizer production.

### b) Process Description

Single superphosphate is prepared by reacting ground phosphate rock with sulphuric acid. In the process, acid and phosphate rock are mixed in a reaction vessel, held in a den, while the reaction mixture solidifies and is then transferred to storage for curing. Following curing, the product may be ground and bagged or be granulated and dried. In granulation, the aired product is: crushed, ground and screened; put through a rotary drum granulator; put through a rotary dryer; cooled in another rotary system; and finally, bagged or stored for bulk sale. Triple superphosphate is produced in a similar manner, with phosphoric acid being used in place of sulphur acid. Ammonium phosphates are also produced in a similar manner when phosphoric acid is treated or neutralized with ammonia under controlled conditions. (Environment Canada 1983, U.S. EPA 1985)

The major emissions sources for these processes are: rock unloading, handling and feeding (particulate emissions of phosphate rock dust); the mixer (reactor), den and curing building (gaseous HF and $SiF_4$, CO and particulates composed of fluoride and phosphate material); and fertilizer handling operations (fertilizer dust). Rock handling operations are normally controlled with a baghouse. Emissions from the reactor, den and granulator are typically controlled with a wet scrubber. Emissions from the dryer, cooler, screens, mills, product transfer systems and storage are sent to a cyclone separator for removal of a portion of the dust before going to wet scrubbers. (Environment Canada 1983, U.S. EPA 1985)

Phosphate production SCCs are as follows (U.S. EPA 1987):

| SCCs | Description |
|---|---|
| 3-01-028-XX | Normal superphosphate |
| 3-01-029-XX | Triple superphosphate |
| 3-01-030-XX | Ammonium phosphates |

## c) Inventory Approach

Phosphate production facilities are inventoried as point sources. Site-specific emission data is preferred. However, literature-based emission factors may be used in conjunction with site-specific process and production data.

## d) Preferred Emission Estimation Procedure

Site-specific emission estimates may be based on the following information:

- site-specific process information, including information on process steps, process control used at each step, fugitive emission control procedures, rated efficiencies for any control procedures
- site-specific emission information based on source testing, licensing information
- production data (including scheduling if temporal data is required)
- emission factors based on production data (weight of product) are available in AP-42 for controlled particulate matter emissions (U.S. EPA 1985)
- emission factors for controlled $SO_x$, $NO_x$ and VOC emissions are also available for some of the process steps in the report on factors used in the 1985 NAPAP Inventory (U.S. EPA 1987)

- particulate emission factors are also available in a report by SNC/GECO Canada Ltd. and ORF (1981)

## e) Activity Level

Statistics Canada issues an annual report on the chemical fertilizer and fertilizer materials industry (Report 46-250B-3721).

Energy Mines and Resources also reports on the phosphate fertilizer industry in its annual Canada Minerals Yearbook. In the 1989 edition, details were provided on the company, location, annual capacity, operations and principal end products.

## f) Alternative Emission Estimation Procedure

If no site-specific information is available, total annual production data can be apportioned to the various plants, based on operating capacities. Typical controls can then be assumed to be in effect (see Environment Canada 1983) and particulate emissions predicted using the literature emission factors outlined in Section e).

## g) Temporal Variability

No temporal data was identified for this sector.

## h) Geographical Variability

Phosphate production facilities are inventoried as point sources.

## i) Point Source Establishments

The following producers are currently listed in the Residual Discharge Information System maintained by Environment Canada:

| Province | Plant ID | Plant Name | Location |
|---|---|---|---|
| New Brunswick | 130010 | Belledune Fertilizer | - |
| Manitoba | 460010 | Simplot Chemical Co. Ltd. | - |
| Alberta | 480013 | Esso Chemical Ltd. | Edmonton |
|  | 480010 | Sherritt Gordon Mines Ltd. | - |
|  | 480012 | Western Co-op Fertilizers Ltd. | Calgary |
|  | 480011 | Western Co-op Ltd. | - |

The following plants (all ammonium phosphate) are listed in the 1989 Canadian Minerals Yearbook:

| Company | Plant Location |
|---|---|
| Belledune Fertilizer (div. of Noranda) | Belledune, New Brunswick |
| Cominco Ltd. | Trail, British Columbia |
| Esso Chemical Canada | Redwater, Alberta |
| Sherritt Gordon Limited | Fort Saskatchewan, Alberta |

## References - Section A.37.7

Energy, Mines and Resources Canada, 1989. "Canadian Minerals Yearbook".

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, annual. "Chemical Fertilizer and Fertilizer Materials Industry". Catalogue No. 46-250B-3721.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". EPA-600/7-87-015. Prepared by Radian Corporation. U.S. Environmental Protection Agency, Washington, DC.

## A.42.1 APPLICATION OF SURFACE COATINGS (SIC 42751)

### a) General Description

Emissions from this sector are mainly hydrocarbons with some sulphur dioxide and nitrogen oxides from ovens. Surface-coating operations primarily involve the application of paint, lacquer, varnish or paint primer for decorative or protective purposes. The major Canadian surface coating applicators include the automobile, strip, sheet and coil coating and household appliance manufacturing industries (Environment Canada 1983). Coating operations can be separated into two groups, industrial and non-industrial. Industrial surface coating operations, for large volume items such as automobiles, appliances, paper, fabric and cans, can be treated as point sources. Small industrial coating operations, as well as non-industrial coating, which includes refinishing of automobiles and architectural coatings, are inventoried as area sources.

Architectural surface coatings (trade paints) are primarily used by painting contractors and home owners (U.S. EPA 1981). Table A.42.1-1 provides a list of typical solvents used in the paint, varnish and allied industries.

### b) Process Description

This sector includes a wide variety of operations (U.S. EPA 1987):

Coating Application - General (SCC 4-02-001 to -007):
This SCC includes the use of solvent and water-based paints as well as varnish, shellac, lacquer, enamel, primer and adhesives. These coatings would include architectural and home application. Area source methods should be used.

Coating Oven - General (SCC 4-02-008 and 4-01-010):
Some coatings are baked after application. Sulphur and nitrogen oxides are emitted as well as VOC.

Thinning Solvents (SCC 4-02-009):
A variety of thinning solvents are consumed in coating operations for clean-up as well as adjusting formulations. U.S. EPA 1987 lists emission factors for 28 solvents in use under this SCC.

Fabric Coating/Printing/Dyeing (SCC 4-02-011/-12/-13):
These coating operations are carried out on continuous lines. Other coating operations are carried out by dipping, spraying or electrodeposition. Table A.42.1-2 lists the SCCs covered by these operations.

Emission control equipment used in the surface coating industries may be designed to: (i) recover solvents for recycle, such as carbon adsorbers, absorbers or condensers and, ii) destroy VOC emissions by means such as incineration. In general, other than for solvents retained by the product, incinerated, or recovered and sold for other uses, all solvents consumed in coating operations are emitted to the atmosphere. Lee et al (1990) in CCME (1990) gives a review with examples of control equipment and control efficiencies for VOC emissions from this sector.

Canadian VOC emissions inventories have been prepared under the following SCCs:

| | |
|---|---|
| SCC 77000 | Application of surface coating - trade, sales use |
| SCC 78200 | Application of surface coating - industrial use |
| SCC 4-02-001 | General solvent-base coating |
| SCC 4-02-005 | Coating application - enamel |
| SCC 4-02-015 | Magnet wire surface coating |
| SCC 4-02-016 | Surface coating - automobiles and trucks |
| SCC 4-02-017 | Surface coating - metal cans |
| SCC 4-02-025 | Coating of miscellaneous metal parts |

The manufacture of coating materials (SIC 37510) is included under the Chemical Process Industries and only application operations should be included in this sector.

## c) Inventory Approach

The overall approach for preparing an emissions inventory for surface coating operations is through mass balance. In order to prepare a mass balance on a point or area basis, the following components must be estimated:

- solvents consumed by the coating operation/s.
- solvents retained by the product or converted to product,
- solvents destroyed or removed from the operation through incineration, sale for other uses or other removal pathway.

Solvents contained within surface coating liquids are almost totally evaporated during the application of paint, lacquer, varnish and paint primer. Non-industrial and small industrial VOC emissions are, therefore, calculated on an area source basis using the mass balance approach. The total national emissions are calculated based on solvent consumption and then apportioned to provincial regions based on available statistics. (Edwards and Cotton 1988)

Emissions from industrial coating operations can also be prepared using a mass balance on a national or provincial basis. In order to resolve the emissions to sub-provincial or modelling grid scales, however, requires a point-by-point mass balance for the larger industrial sources.
CCME (1990) gives a detailed account of the methods used to prepare VOC emissions estimates from a number of sectors including surface coating. It is recommended that this report be referenced in preparing such an inventory. The report deals with the following emissions sources individually:

- Paint/coating application
    - industrial
    - non-industrial
- Application of glues and adhesives
- Printing Industry
- Metal degreasing
- Dry cleaning
- Consumer products

- Pest control products
- General purpose solvent use
- Miscellaneous industries

Only the first of these sources is included under this SIC. In order to ensure a proper accounting for all solvent use, it is recommended that in preparing a mass balance, base quantity data for all these sources be developed as a group to avoid double-counting and omissions. (See also Dry Cleaning (SIC 97211); General Solvent Use (SIC 65321)).

## d) Preferred Inventory Approach

The main information sources to be used for preparing an emissions inventory for this sector are CCME (1990) and Levelton (1979). Emission factors provided in these documents should be used in preference to the NAPAP 1985 factors (U.S. EPA 1987). Non-industrial and minor industrial sources should be inventoried on an area basis. Major industrial sources should be inventoried as point sources.

Other than for solvents, which are destroyed or otherwise converted, all the solvents consumed by the solvent use sectors are emitted as VOC. It is, therefore crucial that a proper and accurate solvent mass balance be prepared for these sectors. Miasak (1988) has prepared a detailed breakdown of solvent use in 1988 using the following sources:

- Corpus Information Services CPI Product Profile
- SRI International Chemical Economics Handbook
- Chem System Inc. (1987). Prospectus for Hydrocarbon Solvents in a Changing Environment

The results of this analysis are provided in CCME (1990). Other sources of data specific to the surface coating sector are:

- Statistics Canada (46-250), which provides domestic shipments and values of shipments of paints and allied products.

- Levelton (1979), which provides an extensive study of point source emissions from primary industries such as surface coating of automobiles, furniture, appliances and farm machinery.

Paint use statistics on a national basis are obtainable from Statistics Canada 46-250 for:

- paint:oil base
- paint:water base
- varnish/shellac
- lacquer
- enamel
- primers/sealers
- stains
- thinners

Emission factors for each of these coating materials, based on total paint volume applied, are provided in CCME (1990). These emission factors are essentially the fraction of solvent in each paint type.

Total paint usage must be subdivided into trade sales (to home owners and painting contractors) and major industrial use (to be regarded as point sources). Emissions due to trade sales are essentially uncontrolled, whereas industrial operations may collect and recover or destroy some emitted solvents.

The preferred method of estimating industry useage of paint and allied products is through a survey of the major contributing industries. Such a survey should, as a minimum, obtain data on the volumes of coating materials used and the emission control devices used for each operation. Where available, control device efficiency data should be compiled. Volumes of coating materials used by minor industrial sources, homeowners and painting contractors, can be obtained by difference and apportioned to provincial or finer geographical resolution by population.

The steps to be followed in preparing an emissions inventory for this sector are as follows:

(i) Project the Miasek (1989) solvent use data to the year of interest using Statistics Canada 46-250.

(ii) Conduct an industry survey of industrial coating operations to determine quantity and type of paint used, solvent content (maybe from paint manufacturer)), emission control methods and efficiency. Table A.42.1-3 lists industries which may be included in the survey.

(iii) Based on solvent content of various paint types (from survey or from CCME 1990), estimate industrial solvent use by major establishment; by difference with Miasek data estimate non-industrial and small industrial solvent use for coating applications.

(iv) Using destruction and removal efficiency estimates from survey data or U.S. EPA (1987), calculate major industrial emissions on a point source basis.

(v) Emissions from non-industrial and small industrial coating operations are uncontrolled and the total solvent consumed is emitted to the atmosphere.

### e) Activity Level

For this sector, activity level is inferred directly from consumption data, as discussed in Section d).

### f) Alternative Emission Estimation Procedures

A less detailed method of estimating emissions from this sector is available in CCME (1990). As for the preferred method (Section d), consumption statistics for the various coating materials should be compiled using the Miasek (1989) data. The percentage of trade sales for each coating material from Levelton et al (1976) is estimated to be 41%. After applying the emission factors available in CCME (1990), the emissions resulting from trade sales are distributed according to population. The balance of the emissions due to industrial use can be distributed by industrial labour force statistics available from Statistics Canada.

## g) Temporal Variability

Generalized seasonal, daily and hourly temporal factors by province have been estimated for the application of surface coatings (MEP/ORF 1985). More detailed estimates of the temporal distributions of industrial sector emissions could be obtained through industry survey of major establishments if the preferred inventory method of Section d) is used.

## h) Geographical Variability

The geographical distribution of the emissions is determined by the locations of the major point sources and the distribution of population as is described in Section f).

## i) Point Source Establishments

To be compiled from Provincial Ministry Data and trade publications.

# TABLE A.42.1-1

## Typical Solvents Used in the Paint, Varnish and Allied Industries
Lee et al (1990) in CCME (1990)

---

Mineral Spirits
Kerosene
Naphtha
Benzene
Toluene
Xylene
Pine Oil
Turpentine
Methanol
Ethanol
n-Propanol
iso-Propanol
n-Butanol
iso-Butanol
sec-Butanol
tert-Butanol
Glycols
Glycol esters
Acetone
Methyl ethyl ketone
Methyl iso-butyl ketone
Ethyl acetate
Isopropyl acetate
n-Butyl acetate
Glycol ether acetate
Methylene chloride
Trichloroethylene

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## TABLE A.42.1-2

## SCCs Covered by Other Coating Operations

| Process | SCC |
|---|---|
| Large appliances | 4-02-014-XX |
| Wire | 4-02-019-XX |
| Automobile and Light Trucks | 4-02-016-XX |
| Metal cans | 4-02-017-XX |
| Metal coils | 4-02-018-XX |
| Wood furniture | 4-02-019-XX |
| Metal furniture | 4-02-020-XX |
| Flat wood products | 4-02-021-XX |
| Plastic parts | 4-02-022-XX |
| Large ships, aircraft | 4-02-023-024 |
| Metal parts | 4-02-025-XX |
| Steel Drums | 4-02-026-XX |

(U.S. EPA 1987)

## TABLE A.42.1-3

## Industries which Involve Surface Coating Application

| SIC | Industry |
|---|---|
| 15990 | Rubber products |
| 19300 | Wool and yarn mills |
| 21600 | Carpet, mat and rug industry |
| 25200 | Plywood and veneer |
| 25420, 25810 | Cabinets and caskets |
| 27400 | Paper products |
| 29200 | Steel pipe and tube industry |
| 29511 | Aluminum products |
| 30400 | Metal stamping, pressing, coating |
| 30700 | Heating equipment |
| 31100 | Agricultural implements |
| 31800 | Office, store machinery |
| 32300, 32310, 32500 | Motor vehicle industry |
| 32600 | Railroad rolling stock |
| 32710 | Shipbuilding and repair |
| 33800 | Electrical wire and cable |
| 35111 | Clay products |
| 41210 | Bridge, road construction |
| 42751 | Painting and decorating |
| 64200 | Department stores |

## References - Section A.42.1

Canadian Council of Ministers of the Environment (CCME) 1990(a). "Control Technologies for Management of Nitrogen Oxides ($NO_x$) and Volatile Organic Compounds (VOC) in Canada; Work Sub-Group 6.4: Products Substitution and Miscellaneous Sources - VOC". Report prepared by Public Public Consultation Multistakeholder Work Sub-Groups on $NO_x$/VOC Control Technologies.

Edwards, W.C. and T. Cotton, 1988. "VOC Emissions Methods Manual". Report prepared for Environment Canada by B.H. Levelton and Associates.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)" Prepared by Environmental Protection Programs Directorate, Report EPA 3-EP-83-10.

Lee, N., W.C. Edwards and D.J. Herbert (1990). "Reduction of VOC Emissions from Solvents by Product Substitution, Process Changes or Add-on Controls". Report prepared for Environment Canada by B.H. Levelton and Associates.

Levelton, B.H. (1979). "Review of Surface Coating Industry Atmospheric Emission Sources and Control Technology". R.H. Levelton and Associates Ltd. Report prepared for Environment Canada.

MEP Company and Ontario Research Foundation (MEP/ORF), 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Report prepared for Environment Canada.

Miasek, P.G., 1989. Esso Chemical Canada, Personal Communication to Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1981. "Procedures for Emission Inventory Preparation. Volume III, Area Sources". EPA-450/4-81-026c. NTIS PB82-240128.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory". Report prepared by Radian Corp. NTIS PB87-198735.

## A.47.1 GRAIN ELEVATORS (SIC 47100)

### a) General Description

Grain elevators are primarily transfer and storage units. They are divided into four groups based on their location and function:

| SIC | SIC Name |
|---|---|
| 47110 | Grain Handling and Milling - Terminal Elevator |
| 47111 | " " " " - Primary Elevator |
| 47112 | " " " " - Transfer Elevator |
| 47113 | " " " " - Process Elevator |

Particulate matter is the only emission inventoried from this sector.

### b) Sector Description

Primary elevators receive grain by truck from producers for either storage or forwarding. These elevators sometimes clean or dry grain before it is transported to terminal or process elevators. (U.S. EPA 1985)

Terminal elevators dry, clean, blend and store grain for shipment to transfer, other terminal (for export) or process elevators.

Transfer elevators generally perform the same function as terminal elevators.

At any grain elevator, the first step is the unloading of the grain from the incoming truck, railcar or barge into a hopper. The grain is then transferred to the main part of the elevator, the headhouse, by a conveyor. In the headhouse, grain is lifted on an elevator leg and discharged in a gallery belt. The gallery belt transfers the grain to storage, where a tripper diverts grain into the proper bin or silo. Grain is often cleaned and/or dried before storage. Grain is discharged from storage to loadout via tunnel belts which run below the bins. (U.S. EPA 1985)

Process elevators are actually grain processing plants or mills. While the elevator operations of unloading, conveying and storing are performed at these locations, they also include direct manufacturing or processing of grain for use in other products. The principal function in this regard is milling. (U.S. EPA 1985)

Table A.47.1-1 summarizes these functions by area source SCC.

Point source SCCs are also available to characterize these functions for larger elevators. These are listed in Table A.47.1-2. Note that SCCs 3-02-005-XX and 3-02-006-XX are terminal and primary elevators, SCCs 3-02-007-XX are all process elevators, SCCs 3-02-008-XX could be classified as either terminal or process elevators, and SCCs 3-02-031-XX are similar to transfer elevators.

Significant particulate emission sources for grain handling operations include grain dryers and cleaners. The amount of dust emitted during the various operations depends upon the type of grain being handled, its quality or grade, its moisture content, the degree of enclosure at loading and unloading areas, and the extent and efficiency of dust containment systems used. Process elevators have additional particulate emissions from the milling operations. (U.S. EPA 1985)

Grain handling operations are often controlled with cyclones or fabric filters. In its 1978 inventory, Environment Canada (1983) assumed 80% fabric filters and 20% medium efficiency cyclones for terminal and transfer elevators with an overall efficiency of 90%. Grain handling operations in primary and process elevators were assumed to all be controlled with medium efficiency (75%) controlled cyclones. Milling operations were assumed to be controlled by baghouses with an overall efficiency of 97%.

## c) Inventory Approach

Grain processing operations may be inventoried as point or area sources. It is recommended that large elevators or milling operations be inventoried as point sources, with the remaining facilities being inventoried as area sources of particulate matter. Site-specific emission information is preferred for those sites inventoried as point sources. However, grain elevator and milling operations may also be inventoried using emission factors based on the mass of grain processed, shipped or received. The specific type of emission factor chosen will depend upon the type of base quantity information available. Control efficiencies are also accounted for in emission estimation.

## d) Preferred Emission Estimation Procedure

For grain handling operations, including cleaning and drying, emission factors may be based on the amount of grain processed, the amount received or the amount shipped. Therefore, the type of base quantity available must be determined before developing suitable emission factors. Particulate matter emission factors are available in the following references:

- AP-42, Supplement B, presents uncontrolled emission factors based on the unit weight of grain handled for each type of elevator. Conversions to weight shipped or received are also available. Uncontrolled emission factors for processing operations based on weight of grain entering the plant are provided by type of grain. (U.S. EPA 1985)
- Environment Canada presents emission factors for the four different types of elevators which roughly correspond to the area source SCCs listed in Table A.47.1-1. These uncontrolled emission factors are based on weight received/shipped. (Environment Canada 1983)
- a report on a fine particulate matter inventory gives controlled and uncontrolled total particulate matter emission factors for each type of elevator. However, these are not broken down into process steps and so cannot be used for a detailed inventory. (SNC/GECO Canada Ltd. and ORF 1981)

For elevators and mills inventoried as point sources, the following site-specific information is necessary to develop emission estimates:

- a description of all process steps

- any site-specific information on emissions from unloading, conveying, drying, cleaning, headhouse, tripper, milling and shipping operations. These may be based on measurements related to production data or on operating permits.
- details on the weight of grain that goes through the above operations (i.e., not all grain may be cleaned or dried). Information on the type of grain is only required for milling operations.
- details on the type and efficiency of process controls installed on each of the above operations.

This information can be used to characterize emissions either through site-specific measurements or through literature-based emission factors corrected with site-specific control information on a step-by-step basis.

For area source calculations, emissions are based on emission factors suitable to the base quantities available and corrected using typical process control characterizations (see Section b). Note that base quantity information must be corrected for those quantities already accounted for in the point source evaluation. Milling emissions estimates may be based on the type of grain, although to date in Canada only wheat milling has been inventoried.

### e) Activity Level

The Canadian Grain Commission maintains information on elevator and milling operations in Canada. Provincial agriculture, trade and environment ministries may also be approached for information on the location, capacity and throughput of these operations. This information should give some indication of potential major emitters for use in listing facilities as point sources.

Facilities identified as point sources should be contacted directly for base quantity information (see Section d). Alternatively, total grain base quantity information may be apportioned to point sources based on the portion of total grain handling or milling capacity that they represent.

Statistics Canada issues an annual report called "Grain Trade of Canada" (22-201), as well as a monthly "Cereals and Oilseeds Review" (22-207). These reports include information on the receipt and shipments of grain at primary and terminal elevators, the movement of grain within Canada, exports and domestic processing data.

Point source base quantities must be subtracted from the total base quantities obtained from these references, in order to derive area source base quantities.

### f) Alternative Emission Estimation Procedure

If resources are not available, the grain handling and milling industry may be inventoried as an area source of particulate matter, using emission factors and base quantities as described in Sections d) and e), respectively.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors for the grain handling and milling sectors are provided in a report by The MEP Company and Ontario Research Foundation (1981).

### h) Geographical Variability

Geographical apportionment may be based on licensing information, information on elevator capacities, or provincial grain handling and milling base quantities as available.

### i) Point Source Establishments

The following grain handling and milling elevators are listed on the Residual Discharge Information System maintained by Environment Canada:

| SIC | Plant ID | Plant Name | City |
|---|---|---|---|
| 47110 | 590646 | Prince Rupert Grain Ltd. | Prince Rupert, B.C. |

# TABLE A.47.1-1

## Description of Area Sources SCCs Available for Use in Classifying Grain Elevator Processes

| SIC | Elevator | SCC | SCC Description | Comments |
|---|---|---|---|---|
| 47110 | Terminal | 61110 | Shipping | Unloading, loading |
| | | 61120 | Transfer | Tunnel belt |
| | | 61130 | Cleaning | |
| | | 61140 | Drying | |
| | | 61150 | Headhouse | Legs |
| | | 61160 | Tripper | Gallery belt |
| 47111 | Primary | 61410 | Shipping | Unloading, loading |
| | | 61420 | Transfer | Removal from bins |
| | | 61430 | Headhouse | Drying, legs |
| 47112 | Transfer | 61210 | Shipping | Unloading, loading |
| | | 61220 | Transfer | Removal from bins |
| | | 61230 | Headhouse | Drying, cleaning, legs |
| | | 61240 | Tripper | Gallery belt |
| 47113 | Process | 61310 | Receiving | Unloading |
| | | 61320 | Precleaning | |
| | | 61330 | Cleaning | |
| | | 61340 | Millhouse | |

### TABLE A.47.1-2

### Point Source SCC Categories Available for Use in Classifying Grain Elevator Processes (U.S. EPA 1987)

| SCC | Description |
|---|---|
| 3-02-005-XX | Feed and Grain Terminal Elevators |
| 3-02-006-XX | Feed and Grain Country (Primary) Elevators |
| 3-02-007-02, 05 | Barley Milling |
| 3-02-007-04 | Milo Milling |
| 3-02-007-11 to 14 | Drum Mills |
| 3-02-007-21 to 24 | Rye Milling |
| 3-02-007-31 to 34 | Wheat Mills |
| 3-02-007-41 to 45 | Dry Corn Milling |
| 3-02-007-51 to 56 | Wet Corn Milling |
| 3-02-007-60 | Oat Milling |
| 3-02-007-71 to 74 | Rice Milling |
| 3-02-007-81 to 91 | Soybean Milling |
| 3-02-008-XX | Feed Manufacture |
| 3-02-031-XX | Export Grain Elevators |

## References - Section A.47.1

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". EPS 3-EP-83-10. Environment Canada, Ottawa.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Statistics Canada, monthly. "Cereals and Oilseeds Review". Catalogue No. 22-207.

Statistics Canada, annual. "Grain Trade of Canada". Catalogue No. 22-201.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". EPA-600/7-87-015. Prepared by Radian Corporation. U.S. Environmental Protection Agency, Washington, DC.

## A.51.1 GASOLINE MARKETING (SIC 51111)

### a) General Description

The fuel marketing network includes all fuel transfers from the refinery loading rack to the end-user. Volatile components of fuels are emitted as fuel moves from the refinery to the end-user whenever tanks are filled or emptied or while tanks are open to the atmosphere, be they large above-ground tanks, tank trucks, railcars or underground tanks at service stations. In addition, emissions occur from evaporation of fuels spilled during transfer operations.

Figure A.51.1-1 illustrates the modes of transport and rehandling plants used in general for marketing of gasoline. A parallel network is used for marketing diesel fuel. Similar illustration of the fuel marketing networks have been developed for each Province in Canada (PACE 1983). A study of emissions by Province brings to light minor differences which exist in the marketing network between provinces as a result of local market circumstances.

The fuel marketing network is complex. As fuels are moved from source to end-user various sizes and types of tanks and modes of transport are used, each with their own particular emission characteristics. These differences are further affected by seasonal changes in fuel properties and climate (Edwards and Cotton, 1988).

Of the two fuels, gasoline and diesel, the vast majority of VOC emissions occur from gasoline as a result of its much higher vapour pressure. This is illustrated effectively by the results for Vancouver which showed that VOC emissions from marketing of diesel fuel and jet fuels were of the order of 1% of that from gasoline, both for automotive and aviation uses (Environment Canada, 1987).

All emissions which are associated with operations preceding the refinery loading rack, are dealt with under the Petroleum Refining Sector (SIC 36101) and are specifically excluded from the present estimates.

## b) Process Description

VOC emissions occur from the following sources in the fuel marketing network: (Edwards and Cotton, 1988).

Above ground storage:

Fixed roof tanks
- breathing loss from diurnal temperature changes
- working loss from displacement of vapour during filling and outbreath of vapour after rapid liquid withdrawal

Floating Roof Tanks
- standing loss from escape of vapours at the roof seal and other fittings
- working loss from evaporation of liquid left on the exposed tank wall as liquid is withdrawn

Underground Storage Tanks:
- working loss from displacement of vapour during filling. This is the only significant means of emission, breathing losses being minimal because of the stability of earth temperature.

Tank Trucks and Railcars:
- loading loss from displacement of vapour upon filling
- breathing loss during transit as a result of temperature changes

Marine Vessels

- loading loss from displacement of vapour upon filling
- breathing loss during transit as a result of temperature changes

Road Vehicles:

- refueling loss from displacement of vapour as tank is filled. Dispensed fuel and residual fuel in the tank are at different temperatures
- breathing loss as a result of temperature changes
- fuel spillage

Table A.51.1-1 gives a listing of the SIC codes and emission factors which are available from the NAPAP 1985 inventory.

### Tank Storage

In moving fuel from refinery to end user, the fuel passes through the several intermediate storage facilities indicated in Figure A.51.1-1. The storage may be to provide a capacitance to absorb fluctuations in an otherwise continuous flow of fuel, or the storage may be designed to be periodically filled on a withdrawal/refill cycle determined by consumption. Storage may be above or below ground, and several designs are in use with very different emission characteristics.

Fixed roof tanks are essentially constant volume vessels which vent to or from the headspace on filling and emptying. Emissions from the vent may be controlled by providing an expandable vapour reservoir to accommodate volume changes (variable vapour space tanks). Floating roof tanks have a "deck" which floats on the surface of the gasoline and which has a sliding seal at the tank wall. These tanks may be open (external floating roof) or have a fixed roof enclosing the headspace above the deck (internal floating roof). Retrofitted floating decks can be installed inside fixed roof tanks in which case the roof is often supported by internal columns.

Emissions from tankage are of three types:

- breathing losses
- standing losses
- working losses

Breathing losses are due to diurnal changes in temperature and are negligible for underground tanks. Standing losses apply mainly to floating roof tanks and are due to leakage at the sliding seal and fittings on the floating deck. Working losses accompany changes in liquid volume during filling or emptying of the tank. With a floating roof a liquid film is left on the tank wall as liquid is withdrawn. This liquid evaporates either directly to the atmosphere or into the closed space above the floating deck.

### Tank Trucks, Railcars and Marine Vessels

These vessels for transporting gasoline are invariably fixed volume tanks which have loading losses due to displacement of vapour and breathing losses due to temperature changes. The loading losses are to some extent dependent on the manner in which fuel is released into the tank during filling. Filling from the bottom or with a submerged nozzle minimizes vapour entrainment and stripping of high vapour pressure compounds from the fuel in the tank. Such stripping occurs with splash loading due to the nozzle being placed near the top of the tank which allows fuel to fall into the tank.

### Vehicle Refueling

Vapour displacement during tank filling is the major loss during refueling. Due to the smaller mass of fuel in road vehicle tanks, the fuel temperature varies widely with the ambient temperature. The temperature difference between residual fuel in the tank and dispensed fuel has an important effect on the vapour emission.

Emission Controls

The VOC emission from gasoline at all stages of distribution can be reduced by reducing the butane content of the fuel (CCME, 1990). Gasoline vapour pressure is determined by the Reid Vapour Pressure Test (RVP). Currently, the RVP is varied between the summer and winter seasons to reduce emissions without introducing drivability problems.

Another form of control involves recycling displaced vapour from the tank being filled to the increased headspace of the supply tank (vapour balancing). At the refinery bulk terminal, the vapour can be returned to the process. Other control methods are thermal oxidizers, condenser and carbon adsorption with recovery. A discussion of the efficiencies and cost of these control methods is provided in CCME (1990).

### c) Inventory Approach

VOC emissions from gasoline marketing operations are determined primarily by the gasoline throughput of the system to which an emission factor is applied. The level of detail to which the emissions are to be resolved, determines the data required at each stage of distribution as well as the forms of the emission factors used. For relatively coarsely resolved estimates (ie. provincial or Canada wide) area source methodology may be used. Where specific details of storage tank numbers, type and throughput are not available, generalized emission factors are available from NAPAP 1985 (U.S. EPA 1987) as described in Table A.51.1-1. The application of these factors requires estimates of the volumes of fuel stored, throughput, transferred and pumped as well as estimates of the modes of transport used and relative volumes stored in each type of storage vessel; details of individual tanks are not required. This method is only suitable where a rapid estimate of limited accuracy is sufficient.

The accuracy of the emissions estimates can be greatly enhanced by using point source methodology for the refinery loading, bulk terminals, bulk plants and some aspects of transportation. Other than for very specific urban scale inventories, service station emissions are estimated using area source methods.

### d) Preferred Inventory Approach

The overall details of the preferred method of compiling an emissions inventory from this sector are provided in Environment Canada (1987 and 1988). The detailed inventory of service station emissions described in these reports is only suitable for specific urban studies requiring detailed spatial resolution. Instead, area source methods should be used for the service station emissions as described in PACE (1986).

Table A.51.1-2 lists the data requirements for estimating hydrocarbon emissions from this sector. There are three classes of data; firstly, those obtained by questionnaire from individual installations; secondly, those calculated from other data such as fuel type and finally, data such as climatological data which can be extracted from publications. Throughput data provide the base quantities for emissions estimates while other data are used with appropriate algorithms to calculate emission factors.

Questionnaires designed to obtain relevant data from refineries, bulk terminals and bulk plants are provided in Environment Canada (1988). The questionnaires should be sent to all major producers and suppliers of gasoline in the study area. Lists of such establishments can be compiled with the assistance of PACE and Provincial Petroleum Associations.

The responses to the questionnaires will enable the movement of gasoline from the refinery to the end-user to be quantified in terms of terminal throughputs, storage capacity, transport mode and control devices if any. Methods of reconciling these fuel movement estimates with Canadian or Provincial total gasoline production and sales figures are described in PACE (1983), PACE (1986) and Environment Canada (1988). Statistics Canada publications No. 57-003 and 53-218 are required for these calculations; these statistics provide Canadian gasoline and diesel fuel market data on a provincial basis.

Emission factor algorithms are provided in Environment Canada (1987). The algorithms in this reference are based mainly on AP-42 (U.S. EPA 1985) and PACE (1983). In order to compute emission factors for each stage of the gasoline distribution system, certain fuel properties, such as vapour pressure and vapour molecular weight must be estimated based on fuel grade and temperature. Methods for making such estimates are available in Environment Canada (1987) and PACE (1983). AP-42 should also be consulted to provide background for some of the estimation methods and for descriptive diagrams of the various storage vessels. Care should be exercised in using past information on fuel vapour pressure since reductions in Reid vapour pressure are being implemented to reduce emissions from the gasoline marketing sector (CCME, 1990).

### e) Activity Level

The throughput of gasoline at the various distribution points in the marketing system are determined by questionnaire as described in (d) above. Note that the total of all throughputs at all stages will far exceed the initial production at the refinery.

### f) Alternative Emissions Estimation Procedure (Edwards and Cotton 1988)

Given the distributed nature and relatively small quantities emitted from individual sources, an alternate approach is to use the area source methodology on a provincial basis. Use of this approach rather than a point source methodology simplifies the task considerably, especially for emissions from above ground storage tanks (Edwards and Cotton, 1988).

Specific sources of information required for calculation of emissions on a provincial basis are summarized in Table A.51.1-3. All data requirements are based on a simplified emission factor methodology. With this approach, the main data requirement is for the amount of fuel handled at various levels in the fuel marketing network. The quantity of fuel produced at refineries in each province can be obtained from reports submitted by industry to Environment Canada to document lead in fuel and sulphur balances for each refinery. Also, Statistics Canada tabulates gross and net gasoline and diesel sales. From these sources, it is possible to estimate the amount of fuel dispensed at the retail level and the amount distributed at the refinery level. The distribution of fuels to the various intermediate plants in the network and the amounts moved by different modes of transport can in turn be estimated using factors presented by PACE (1983). Their results should be used to estimate the amounts shipped by truck, rail and marine vessels and the amounts stored at the bulk terminals and bulk plants. Because of rehandling, the volumes moved by various means will not equal the amounts actually sold at the retail level. Environment Canada (1987) and PACE (1986) illustrate the process by which the quantity of fuel moved and stored can be estimated.

### g) Temporal Variability

Monthly variation in fuel sales is available from the Statistics Canada reports used in computing fuel throughputs. Through the application of emission factors, monthly temporal variability is compiled. Day-of-week and diurnal variations in fuel movements from the refinery, bulk terminals, bulk plants and service stations are provided in Environment Canada (1987) and (1988).

### h) Geographic Variability

The emissions estimates are prepared on a provincial basis. If the preferred inventory method is used, then other than for service stations and bulk users, the point source methodology enables the emission sources to be assigned to actual locations. Service station and bulk user emissions can be gridded by population and industrial labour force respectively.

## TABLE A.51.1-1

## Emission Factors from NAPAP 1985.(U.S. EPA 1987)

(i) Petroleum Product Storage at Refinery

| | |
|---|---|
| 4-03-010-XX | Fixed roof tanks breathing and working losses |
| 4-03-011-XX | Floating roof tanks standing and withdrawal losses |
| 4-03-012-XX | Variable vapour space tanks filling loss |
| 4-03-888-XX | Petroleum storage tanks - fugitive emissions |

(ii) Petroleum Storage at Bulk Terminals

| | |
|---|---|
| 4-04-001-XX | Breathing, working, standing, filling and fugitive losses |

(iii) Petroleum Storage at Bulk Plants

| | |
|---|---|
| 4-04-004-XX | Underground tanks; breathing and working losses |

(iv) Petroleum Transportation and Retailing

| | |
|---|---|
| 4-06-001-XX | Tank cars and trucks |
| 4-06-002-XX | Marine vessels |
| 4-06-003-XX | Storage tank filling and storage at retail outlets |
| 4-06-004-XX | Filling vehicle gas tanks |
| 4-06-888-XX | Fugitive emissions |

## TABLE A.51.1-2

## Data Requirements for Calculation of Hydrocarbon and Benzene Emissions (PACE 1986)

---

Installation Specific

(*) Tank type
(*) Capacity
(*) Dimensions
(*) Paint colour
(*) Internal condition
(*) Vapour control methods
(*) Seal type and condition
(*) Construction method
(*) Deck fittings
(*) Loading method (to transfer vehicle)

Product Related

(*) Type of gasoline
(*) Throughput
(a) Vapour pressure
(a) Molecular weight
(a) Liquid density
(*) Benzene content
(*) Average delivery to service station
(*) Average tank contents at delivery

Climatological

(p) Monthly average air temperature
(a) Monthly average underground temperature
(p) Average diurnal temperature change
(p) Average atmospheric pressure
(p) Monthly average wind speed

---

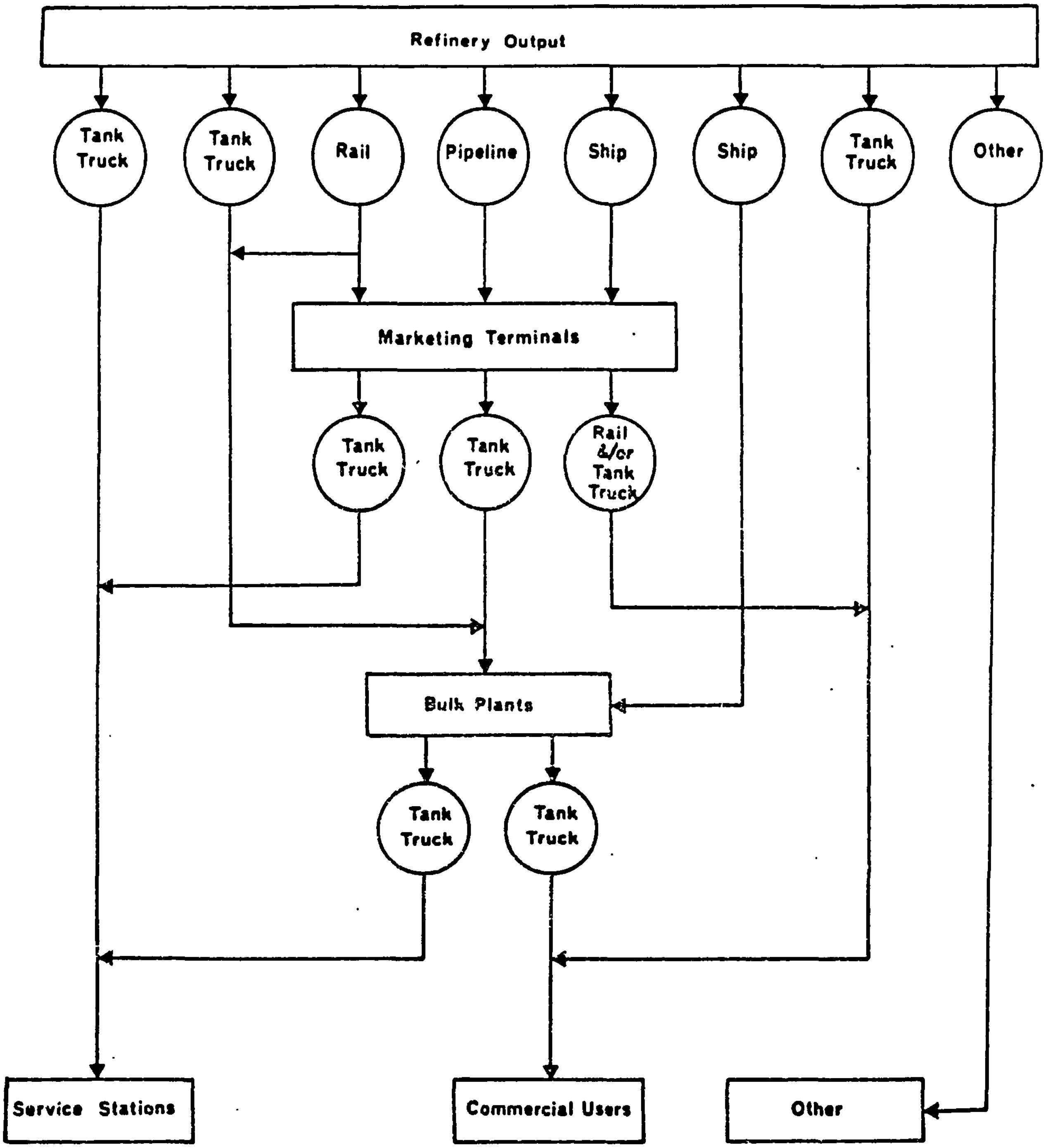
* Obtained from specific facilities by questionnaire
(a) Calculated from available data
(p) Available from publications

## TABLE A.51.1-3
## Data Procurement Source (Edwards and Cotton 1988)

| Emission Source | Data | Primary Source | Secondary Source |
|---|---|---|---|
| Above-ground tanks at refineries, bulk terminals and bulk plants | Provincial throughput | Statistics Canada reports 57-003 and 53-218. PACE (1983) | Environment Canada industry reports for lead and sulphur in fuels. |
| | Emission Factor | PACE (1986) and Environment Canada (1987) | NAPAP<br>U.S. EPA AP-42 |
| Truck and Railcar | Provincial throughput | Statistics Canada reports 57-003 and 53-218, and PACE (1983) | Environment Canada industry reports for lead and sulphur in fuels |
| | Emission factor | PACE (1986) | NAPAP<br>U.S. EPA AP-42 |
| Marine Vessels | Provincial throughput | Plant contact | PACE (1983)<br>Statistics Canada |
| | Emission factor | U.S. EPA AP-42 | |
| Service Stations and bulk users | Provincial throughput | Statistics Canada reports 57-003 and 53-218. PACE (1983) | Kent Marketing reports on fuel sales. Industry. |
| | Emission factor | Environment Canada (1987)<br>PACE (1983). | U.S. EPA AP-42 |

## FIGURE A.51.1-1

## Gasoline Marketing Distribution System (PACE, 1986)



## References Section A.51.1

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U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory. Report prepared by Radian Corp. NTIS PB87-198735.

# A.65.1 GENERAL SOLVENT USE (SIC 65321)

## a) General Description

The general solvent use sector has in prior methodology been used to cover a wide variety of operations which emit solvents other than surface coating or dry cleaning . As more refined inventory methods and more detailed use information have become available, it is possible to inventory this sector in more detail. Lee et al (1990) as reported in CCME (1990), divides solvent use into nine sectors and sub-sections as follows:

- Paint/coating applications (SIC 42751)
- Dry cleaning operations (SIC 97211)
- Pest control products (SIC 02220)
- Application of glues and adhesives
- Printing industry
- Metal degreasing
- Consumer products
- General solvent use (SIC 65321)
- Miscellaneous industries

It is recommended that other than for paint/coating application, dry cleaning and pest control products, all other sub-sectors should be inventoried as individual components under the General Solvent use sector. The sector methodology described here should be read in conjunction with the methodologies for the other main sectors in the above list to avoid double counting or omission of emissions from the entire solvent-use sector group.

## b) Process Description

As for other solvent use sectors, the solvents consumed in formulating adhesives, printing inks, consumer products or used in cleaning operations, are emitted as VOC. In large operations such as degreasing, and some printing processes, VOC emissions are controlled through condensation, adsorption or incineration, for example. Of these controls, only incineration significantly reduces VOC emissions but does not affect consumption. Other controls facilitate economy of solvent use, but the net solvent consumption, after allowing for that which is permanently incorporated into the product, is emitted to the atmosphere. CCME (1990) and U.S. EPA (1985) should be referenced for further details of the processes involved in the solvent use categories and only a brief synopsis from this and other references is provided here.

(i) Application of Glues and Adhesives

Glues and adhesives encompass a wide diversity of specialty products that are usually formulated to meet very specific applications. They are used in a large number of manufacturing industries including construction, transportation, electronics, packaging, aircraft, medical and dental, and furniture fabricators, as well as being marketed commercially as a wide variety of consumer end products.

Glues and adhesives, whether of natural or synthetic origin, contain many additives such as pigments, thickeners, wetting agents, preservatives, plasticizers, fillers and solvents. Within this general class, it is the solvent-borne adhesives and sealants which are the main source of VOC emissions. Critical requirements for the solvent are the ability to dissolve all of the various adhesive components, the ability to wet the substrate which promotes adhesion and to have a viscosity which allows uniform application of the adhesive. Table A.65.1-1 lists typical solvents used in glues and adhesives.

VOCs from the use of glues and adhesives are mainly emitted from the evaporation of solvents during application. Little or no VOC is emitted during the curing process.

At the process level, the following SCCs are provided in the NAPAP 1985 emissions factors (U.S. EPA 1987):

SCC 4-02-007-01 Adhesive application (lbs/ton coating applied)
SCC 4-02-007-06 Adhesive solvent mixing (lbs/ton solvent mixed)
SCC 4-02-007-10 Adhesive (lbs/gallon of coating)

As for Surface Coating Applications (SIC 42751), the main emission control devices for large operations are carbon adsorbers or incinerators.

(ii) Printing Industry

Printing inks and associated printing coatings are composed of the same type of ingredients as paints. They consist of pigments, composed of organic and inorganic material to produce the colours desired; solid components or binders, composed of organic resins and polymers to lock the pigment to the "paper"; and solvents, usually composed of organic compounds to disperse the pigments and binders. Of course, they are tailored to have different properties than paints.

The specifications for inks are governed by a number of considerations such as: printing processes and methods, type of press, paper or other substrates, drying process, desired finish, end use of the printed product, colour, fabrication method to which the printed stock will be subjected, and the sequence of ink application in multicolour printing. The emission of VOCs from inks and other printing coatings, whether in the commercial graphic arts industries or use by individual consumers, is a consequence of the solvents used in ink coating formulations. Table A.65.1-2 lists representative solvents used in printing inks.

Industrial and commercial printing establishments employ four basic processes: web offset lithography, web letterpress, rotrogravure and flexography. Printing involves the application of a high solvent content ink to the moving surface of a "web" or film, followed by rapid solvent evaporation by heated air moving across the wet surface. Solvent laden air is exhausted from the system.

Typically, publication ink has a 40% solvent content while newspaper ink has only a 5% solvent content. Both types of solvents are usually petroleum derived hydrocarbons. NAPAP 1985 emission factors (U.S. EPA 1987) are available for the following processes:

| | |
|---|---|
| SCC 4-05-001-XX | Dryers |
| SCC 4-05-002-XX | Printing by press type |
| SCC 4-05-003-XX | Ink thinning solvents |

Various units are used; lbs/ton solvent, lbs/ton ink, for example. VOC is the only emission from these processes. Ink manufacture is included under SCC 3-01-0200XX.

U.S. EPA (1985) details the emission control devices with typical flow diagrams used with the various printing processes. The devices include incineration (thermal or catalytic) for lithography and letterpress and regenerable activated carbon adsorbers for rotogravure and flexography. Table A.65.1-3 lists the main industries which consume printing inks.

### (iii) Metal Degreasing

Degreasing is done as a preparatory step to subsequent operations such as coating, plating repair, assembly and machining. Solvent degreasing (or solvent cleaning) is the physical process of using, in most applications, an organic solvent to remove grease, fat, oils, wax or soil from various metal, glass or plastic items. The types of equipment used in this method can be categorized as cold cleaners, open top vapor degreasers, or conveyorized degreasers. Nonaqueous solvents such as petroleum distillates, chlorinated hydrocarbons, ketones and alcohols are used. Solvent selection is based on the solubility of the substance to be removed and on the toxicity, flammability, flash point, evaporation rate, boiling point, cost and several other properties of the solvent. Many industries do employ water-based alkaline wash systems for degreasing. These systems emit no solvent vapours to the atmosphere.

Regardless of the type of solvent or degreasing equipment used, the primary source of VOC emissions from degreasing operations result from evaporative loss of the solvent during cleaning or from the solvent storage area or recovery system. (CCME 1990)

NAPAP 1985 emission factors (U.S. EPA 1987) are available for the following processes:

SCC 4-01-002-XX:
- Open-top vapor degreasing
- Conveyorized vapour degreasing
- Degreasing units general
- Cold solvent cleaning/stripping

Units are generally lbs/ton solvent consumed. The recovery of spent solvent through distillation is often used for expensive chlorinated solvents (Levelton 1990).

(iv) Consumers Products

This emissions group can be divided into three sub-sectors (CCME 1990):

Automotive Products other than Paint

VOC emissions arise from various products used for general automobile maintenance, the primary ones being radiator antifreeze, windshield washer antifreeze, brake fluid and interior and exterior waxes and cleaners.

Household Products

A large number and great variety of household products emit VOCs because of solvents used in the formulation or as propellants, or both. The emissions from these products are small individually, but significant collectively.

Personal Care Products

Many personal use products emit VOCs during use and after application either from solvents present in the formulation or from volatile organic compounds present in a propellant. The large number of different personal products makes it necessary to consider only the major ones on a generic basis.

### (v) Miscellaneous Industries and General Solvent Use

VOC emissions arise from general solvent use in the industrial, commercial and consumer sectors. Prime areas of general solvent use are in miscellaneous cleaning operations, dilution of concentrated products to concentrations recommended for application, and other comparable industrial, commercial and home uses.

Numerous industries use solvents as raw materials for product manufacture, as transfer agents or diluents as wash-up material, as refrigerants or as "by products". These miscellaneous industries include those listed in Table A.65.1-4. Combined, these industries are the source of a significant fraction of total VOC emissions. (CCME 1990)

## c) Inventory Approach

The preferred method of preparation for an emission inventory for VOC from solvent use, is by the mass balance approach. Most of the solvent used in the various products and operations is ultimately released to the atmosphere. A relatively small amount of consumed solvent is destroyed by control devices or retained permanently by the product. By employing a mass balance approach, making proper allowance for solvent conversion or destruction, ensures that all solvent is accounted for. It is recommended that the mass balance be carried out in conjunction with the Application of Surface Coatings (SIC 42751) and Dry Cleaning (SIC 97211) sectors.

A less accurate method which uses per capita emission factors can be used, although total reliance on these factors will result in total solvent emissions which may be inconsistent or even in conflict with solvent consumption statistics.

### d) Preferred Emissions Estimate Procedure

Miasek (1989) as reported in CCME (1990) has produced, for the year 1988, what is probably the most accurate compilation of Canadian solvent usage (see also SIC 42751 Surface Coating and SIC 97211 Dry Cleaning). Miasek's compilation is based on information and data available from Corpus Information Services CPI Product Profile; SRI International Chemical Economics Handbook; Chem System Inc. (1987) Prospectus for Hydrocarbon Solvents in a Changing Environment. Using activity statistics from Statistics Canada, the Miasek compilation can be projected to other recent years with reasonable accuracy. (See also Dry Cleaning and Application of Surface Coatings). The following statistical reports should be used:

| | | |
|---|---|---|
| Statistics Canada | 46-250: | for Paints and Allied Products and Printing Inks |
| | 46-250B 3792: | for Glues, Adhesives and Sealants |

General population should be used for projecting the solvents used for dry cleaning, and consumer products, and labour force statistics for degreasing and other general solvent use categories. The population derived projections are equivalent to using per capita solvent consumption factors based on the Miasek data.

Since the mass balance is on actual solvent used, emission factors are

1.0 kg emitted/kg consumed, except where VOC is incinerated or otherwise converted to non-volatile product or recovered and sold to an industry which is not included in the mass balance. Data on these removal processes and quantities are not generally available and must be assembled for the inventory.

In order to up-date the information on the general solvent sector controls, an industry survey should be conducted with the following objectives (CCME 1990):

- to identify the type and quantity of products produced and/or solvent used
- to determine the controls on VOC emission which are in use
- to determine how spent solvents are recovered or otherwise disposed of
- to determine the extent to which incineration or other destruction/ removal processes are used to destroy VOC emissions
- to assemble data on collection, destruction and removal efficiencies for control devices

Miasek's data show that in 1988 the Miscellaneous Industries sub-sector accounted for some 16% of solvent use and the individual industries shown in Table A.65.1-4 should be included in the study. Based on the survey results, the amounts of solvents destroyed or otherwise removed can be incorporated into the mass balance for each solvent-use group to arrive at the net VOC emissions.

The following steps should be followed in preparing an emission inventory for the general solvent use sector:

(i) Project the Miasek (1989) solvent use estimates to the year required using Statistics Canada 46-250 and 46-250B 3792 and population statistics. The results of this projection will provide solvent use estimates for:

  - printing processes
  - glues, adhesives and sealants
  - industrial degreasing
  - consumer products
  - general and miscellaneous use

(ii) Identify specific industries in the printing, degreasing and miscellaneous industry categories and conduct a survey to determine the solvent used, processes and emission controls, control efficiency data.

(iii) For large emitters in the survey, determine emissions on an individual basis using the survey data.

(iv) For small industrial operations, compile generalized VOC emissions collection destruction and removal efficiencies and apply these to the solvent consumption estimates.

(v) Solvents used in the adhesives, consumer products and general solvent use sub-sectors are uncontrolled and all solvent is emitted as VOC.

## e) Activity Level

Activity levels form an integral part of the emissions estimation procedure, as described in Section d).

## f) Alternative Emission Estimation Procedure

The recommended alternative procedure differs from the preferred method in that survey methods are not used. It is recommended that the same methods be used to project the Miasek solvent use data to other years, since the required statistics are readily available. This is equivalent to using per capita emission factors based on Miasek data.

For those sub-sectors where VOC is incinerated, the removed amount can be estimated from the emission factors in NAPAP 1985 (U.S. EPA 1987) or

U.S. EPA (1985). Other than for printing operations, most of the consumed solvent is emitted as VOC.

## g) Temporal Variability

Seasonal, daily and diurnal temporal profiles are provided by an Environment Canada study (MEP/ORF 1986).

## h) Geographic Variability

Apportioning national emissions estimates to individual provinces can be achieved using general population statistics and labour force statistics:

| | Population | Labour Force |
|---|---|---|
| Glues and Adhesives | X | |
| Printing Inks | | X |
| Metal Degreasing | | X |
| Consumer Products | X | |
| General | | X |

## i) Point Source Establishments

None.

## TABLE A.65.1-1

## Typical Solvents Used in Adhesives and Sealants

---

Acetone
Amyl Acetate
Amyl Alcohol
Benzene
Butyl Acetate
Butyl Alcohol
Carbon Disulphide
Carbon Dioxide
Chloroform
Cyclohexane
Cyclohexanol
Diisobutyl Ketone
Dioxane
Ethyl Acetate
Ethyl Acrylate
Ethyl Alcohol
Ethyl Ether
Ethylene Dichloride
Ethylene Glycol Butyl Ether
Ethylene Glycol Ethyl Ether
Ethylene Glycol Ethyl Ether Acetate
Ethylene Glycol Methyl Ether
Ethylene Glycol Methyl Ether Acetate
Heptane
Hexane
Isophorone
Methyl Acetate
Methyl Acrylate
Methyl Alcohol
Methyl Chloroform
Methyl Ethyl Ketone
Methyl Isobutyl Ketone
Methyl Propyl Ketone
Methylene Chloride
Naphtha
Propyl Acetate
Isopropyl Alcohol
Propylene Dichloride
Stoddard Solvent
Styrene
Tetrachloroethane
Toluene
Trichloroethylene
Xylene

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Lee et al (1990) in CCME (1990)

## TABLE A.65.1-2

## Representative Solvents Used in Printing Inks

---

Toluene
Xylene
Heptane
Isooctane
Mineral Spirits
Naphtha
Hexane
Propanol
Isopropanol
Methanol
Ethanol
Butanol
Glycols
Glycols
Glycol Esters
Acetone
Methyl Ethyl Ketone
Isopropyl Acetate
Normal Propyl Acetate
Ethyl Acetate

---

Lee et al (1990) in CCME (1990)

## TABLE A.65.1-3

## Industries which Involve Printing Operations

| SCC | Industry |
|---|---|
| 27400 | Paper products |
| 28600 | Commercial printing |
| 28700 | Engraving, stereotyping industry |
| 28900 | Printing and publishing |
| 30400 | Metal stamping, pressing and coating |

## TABLE A.65.1-4

## Miscellaneous Industries Using Solvents

---

Electronics
Pharmaceutical
Food Processing
Natural Oil Extraction
Oil Field Chemicals
Rubber Products
Petroleum Refining
Polyolefin Manufacturing
Water Treatment
Wood Preservation
Mining
Calendering
Metal Rolling
Paint Stripping
Photocopying
Cutback Asphalt Paving
Medical/Dental Products
Research Laboratories
Beer and Wine Production
Whisky Warehousing
Plywood Manufacturing
Textile Products

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Lee et al (1990) in CCME (1990)

## References - Section A.65.1

Canadian Council of Ministers of the Environment (CCME) 1990(a). "Control Technologies for Management of Nitrogen Oxides ($NO_x$) and Volatile Organic Compounds (VOC) in Canada; Work Sub-Group 6.4: Products Substitution and Miscellaneous Sources - VOC". Report prepared by Public Public Consultation Multistakeholder Work Sub-Groups on $NO_x$/VOC Control Technologies.

Department of Trade and Commerce (1982). "An Analysis of the Pesticide Industry in Canada".

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## A.97.1 DRY CLEANING (SIC 97211)

### a) General Description (Lee et al (1990) in CCME 1990)

Dry cleaning involves the cleaning of fabrics with nonaqueous organic solvents. Dry cleaning generally involves three principal steps, identical to those of ordinary laundering in water; washing the fabric in solvent one or more times, extraction of the excess solvent often by spinning, and drying the cleaned fabric in ovens or hot air streams.

Two general types of cleaning fluids are used in the industry and consumer end products. Petroleum solvents, such as Stoddard or 140-F, are inexpensive combustible hydrocarbon mixtures similar to kerosene. Synthetic solvents were introduced to eliminate fire hazards associated with petroleum solvents. These synthetic solvents are the more expensive non-flammable halogenated hydrocarbons. Perchloroethylene and trichlorotrifluoroethane are the two most common synthetic dry cleaning solvents presently in use.

The dry cleaning industry can be divided into three sectors: coin-operated facilities, commercial operations and industrial cleaners. Coin-operated facilities are usually part of a laundry supplying "self-service" dry cleaning for consumers. Only synthetic solvents are used in coin-operated dry cleaning machines, in order to avoid the fire hazards presented by petroleum-based solvents. Commercial operations, such as small neighbourhood or franchise dry cleaning shops, clean soiled fabrics and apparel for the consumer. Generally, perchloroethylene and petroleum solvents are used in commercial operations, but those located in metropolitan areas are often limited to the use of synthetic solvents by local fire regulations. Industrial cleaners are larger dry cleaning plants which supply rental services of uniforms, mats, mops, etc. to businesses or industries. Perchloroethylene is used by all or most of the large industrial dry cleaners in Canada.

The solvent itself is the primary VOC emission from dry cleaning operations. Solvent is given off by the cleaning process in the washing, drying and solvent recovery operations. Control of VOC emissions from the dry cleaning area are, therefore, fundamentally associated with the solvent.

## b) Process Description

Canadian emissions inventories for dry cleaning have been prepared using area source methods under the following SCCs:

| | |
|---|---|
| SCC 7100 | Dry Cleaning |
| SCC 4-01-001-03 | Organic solvent dry cleaning Perchloroethylene general (emission per ton of solvent consumed) |

For the 1985 NAPAP inventory, the following additional SCCs are provided in U.S. EPA (1987):

| | |
|---|---|
| SCC 4-01-001-01 | Perchloroethylene (emission per ton of clothes cleaned) |
| SCC 4-01-001-02 | Stoddard Solvent (emissions per ton of clothes cleaned) |
| SCC 4-01-001-04 | Stoddard Solvent (Emission per ton of solvent consumed) |

Coin-operated facilities are closed cycle in that the solvent is applied to the clothes, the clothes are then washed, drained and dried in the same closed vessel. Solvent (perchloroethylene) is recovered and recycled with some losses to the atmosphere. Commercial operations employing perchloroethylene have efficient solvent recovery systems, since the solvent is expensive. Solids recovered by filtration of used solvent are heated to drive off vapours to a condenser and, in some plants, a carbon adsorption unit. Plants using petroleum solvents do not generally recover solvent vapour from the washer/dryer or filter solids.

On the basis of make-up solvent used by the dry cleaning industry, essentially 100% is emitted as VOC to the atmosphere regardless of the solvent recovery efficiency. Caution should be exercised, however, when an emission factor based on the throughput of clothes is used, since this factor will be sensitive to solvent recovery efficiency.

### c) Inventory Approach

VOC emissions from Dry Cleaning operations should be prepared using the mass balance approach, making due allowance for destruction and removal of solvent emissions from the large cleaning operations. The solvent mass balance is based on Miasek (1989), as reported in CCME 1990b, and should be prepared in conjunction with the General Solvent Use (SIC 65321) and Applications of Surface Coating (SIC 42751) sectors. The methodology for preparing a solvent mass balance for a particular year is described under these other two sectors.

### d) Preferred Emissions Estimate Procedure

The Miasek solvent consumption estimate for dry cleaning is a more accurate estimate than a solvent use figure based on generalized per capita or clothes cleaned emission factor, such as is provided in U.S. EPA 1985 or Environment Canada 1983. The total solvent consumed in the dry cleaning process, however, must be corrected for solvent destroyed by control equipment (incineration) or recovered and sold for other purposes. There are no current data on the recovery and control practices of the dry cleaning industry and these data must be ascertained through a survey of the major dry cleaning plants. The survey should obtain the following data:

- the quantity of solvent used according to dry cleaning solvent type,
- the processes used and the VOC emission control equipment used,
- where incineration is used, the type of vapour containment equipment and its collection efficiency should be included,
- disposal of waste solvent if any.

Large establishments to be surveyed can be obtained from trade indexes and provincial ministries.

Based on the results of the survey an estimate of the dry cleaning solvents destroyed or otherwise removed can be made. The balance of the solvent consumed is emitted to the atmosphere. Surveyed establishments should be maintained as point sources and their solvent usage deducted from the provincial total used for dry cleaning. A per capita emission factor, specific to the inventory year can then be calculated to facilitate the geographical allocation of the remaining dry cleaning emissions by population density.

### e) Activity Level

The activity level of the dry cleaning industry is directly related to solvent consumed, as determined in Section d). The activity level which is relevant for emissions, is the solvent consumption which has been corrected for removal and destruction of vapour.

### f) Alternative Emissions Estimation Procedure

For a less accurate, but likely still very satisfactory, estimate of dry cleaning VOC emissions, an emission factor of 0.55 kg VOC per capita may be used. This factor is based on the Miasek data and assumes that all solvent consumed is emitted as VOC. The solvent type can be divided into perchloroethylene (75%) and petroleum solvent (25%), based on the same data.

### g) Temporal Variability

Typical seasonal, daily and diurnal activity profiles for the dry cleaning industry are provided in MEP/ORF 1985.

### h) Geographical Variability

The VOC emissions estimation procedure described, leads to a national total emission. This total can be apportioned to provincial and sub-provincial areas on the basis of population density.

### i) Point Source Establishments

Area source methodology used. In order to survey current VOC control practices, major dry cleaning establishments can be located with the assistance of provincial Ministries of the Environment.

## References - Section A.97.1

Canadian Council of Ministers of the Environment (CCME) 1990(a). "Control Technologies for Management of Nitrogen Oxides ($NO_X$) and Volatile Organic Compounds (VOC) in Canada; Work Sub-Group 6.4: Products Substitution and Miscellaneous Sources - VOC". Report prepared by Public Public Consultation Multistakeholder Work Sub-Groups on $NO_X$/VOC Control Technologies.

Canadian Council of Ministers of the Environment (CCME) 1990(b). "CCME $NO_X$/VOC Consultation Plan". Report to the Federal-Provincial LRTAP Steering Committee on Status of National Inventory of $NO_X$/VOCs, December 1989, Revised February 1990.

Lee, N., W.C. Edwards and D.J. Herbert (1990). "Reduction of VOC Emissions from Solvents by Product Substitution, Process Changes or Add-on Controls". Report prepared for Environment Canada by B.H. Levelton and Associates.

Miasek, P.G., 1989. Esso Chemical Canada, Personal Communication to Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory". Report prepared by Radian Corp. NTIS PB87-198735.

## B.49.1 THERMAL POWER GENERATION (SIC 49110)

### a) General Description

This sector includes the production of electricity with external combustion fossil fuel-fired boilers or by internal combustion engines. Nuclear and hydro generating stations are not inventoried under this SIC.

Particulate matter, $SO_x$, $NO_x$ and CO are all emitted in significant quantities by this sector. VOCs, although emitted in much smaller quantities, are also inventoried.

### b) Sector Description

The thermal power generation sector includes a wide variety of sources, including external and internal combustors that may be inventoried as point or area sources. Figure B.49.1-1 illustrates the main point and area source classifications currently used by Environment Canada to inventory emissions from thermal power generation. Brief descriptions of external and internal combustors are provided below.

<u>External Combustion:</u>
In pulverized coal furnaces, pulverized coal with the consistency of talcum power is generally entrained in primary air before being fed through the burners to the combustion chamber where it is fired in suspension. Pulverized coal furnaces may be classified as either wet bottom or dry bottom, depending on the ash removal technique. Further classifications are based on the firing position of the burners (single front or rear) wall, horizontally opposed, vertical, tangential, turbo or arch fired. (U.S. EPA 1985)

In cyclone furnaces, crushed low ash fusion temperature coal is fed tangentially to a horizontal cylindrical combustion chamber. The finer coal particles burn while in suspension. The coarser particles are thrown to the walls by centrifugal forces. The walls have a surface coating of molten slag which retains most of these coal particles until they are burned. (U.S. EPA 1985, Shih et al 1980)

Mechanical stokers burn coal in fuel beds (as opposed to burning in suspension). All mechanical stokers feed coal onto a grate with provisions for ash removal. The spreader stoker, most common in utility applications, introduces coal into the furnace over the fire bed with a uniform spreading action. Combustion occurs partly in suspension and partly on the grate. Flyash reinjection from mechanical collectors is commonly employed to improve boiler efficiency. Anthracite coal is burned in travelling grate stokers because of the high ignition temperature. In these, coal is fed onto a travelling or vibrating grate and burns as it travels through the furnace. (U.S. EPA 1985, Shih et al 1980)

Coal handling operations such as loading and transfer result in the emission of particulate matter.

Residual oil utility boilers have burner arrangements similar to those for pulverized coal-fired utility boilers. Tangential, front wall and horizontally opposed are the primary firing configurations. Distillate oil and natural gas are primarily used for start-up and flame stabilization in boilers, and distillate oil is blended with residual oil to reduce the total sulphur content of the fuel oil consumed. (Shih et al 1989)

Three main types of emissions control are used for utility boiler emissions reduction: boiler modification, fuel substitution and flue gas cleaning. Boiler modification includes any physical change in the unit or its operation. Fuel substitution involves the firing of "cleaner" fuels either by substitution or blending.

Flue gas cleaning on utility boilers is mainly directed at reducing emissions of particulates and sulfur dioxides.

For particulate control, electrostatic precipitators are the most common control for pulverized and cyclones, while multiple cyclones are generally used for stokers and oil-fired units. (Only 20 percent of oil-fired units were estimated to have particulate control in 1976.) Natural gas-fired units do not normally have particulate control. Other particulate control devices include fabric filters (baghouses) and scrubbers. (U.S. EPA 1985, Shih et al 1980)

Flue gas desulphurization (FGD) processes can be wet, semi-dry or dry. Wet systems, the most commonly applied system, generally use alkali slurries as the adsorbent medium. Particulate reduction of up to 99 percent is also possible with wet scrubbers, but flyash is often collected by upstream ESPs or baghouses to increase the efficiencies and lifespan of these units. FGD units are largely used on bituminous and lignite coal-fired units, although some oil-fired units do have these installed. (U.S. EPA 1985, Shih et al 1980)

### Internal Combustion:

Internal combustion sources include a wide variety of fuels, equipment designs and applications. A U.S. EPA review of internal combustion sources (Shih et al 1979) identified gas turbines and reciprocating engines for electricity generation and industrial applications as having the most potential of the internal combusters for significant emissions of criteria pollutants.

Gas turbines include simple open cycle, regenerative open cycle and combined cycle turbines. The regenerative open cycle type is a very small portion of the total turbine population and emissions from identical gas turbines used in the combined cycle and in the simple cycle are identical. Simple cycle gas turbines may be natural gas-fuelled or distillate oil-fuelled (diesel). (Shih et al 1979)

Reciprocating engines are either spark ignition (gasoline-fuelled) or compression ignition (diesel-fuelled). Spark ignition engines are rarely used for electricity generation because of their poor part-load economy and cost of fuel. (Shih et al 1979)

Air emissions control equipment is not usually installed on gas turbines or reciprocating engines. (Shih et al 1979)

### c) Inventory Approach

Depending on the size of the utility plant and the type of primary and secondary start-up fuel fired, the sources within the Power Generation sector may be either point or area sources. A complete list of power generating sites for each province should be assembled showing the type of primary fuel and stand-by fuel fired, the type of generating system (external combustion boiler or internally fired engine), and their annual fuel consumption. Using the appropriate NAPAP emission factors (SCC 1-01-XXX-XX and 2-01-XXX-XX) (U.S. EPA 1987) those sites expected to meet point source criteria can be determined based on fuel consumption. (Edwards and Cotton 1988)

For point sources, the preferred inventory method is to obtain emissions data based on source testing directly from provincial utilities and electrical commissions. Failing site-specific source test data, emission estimates will be based on process data, fuel data, mass balance estimates and, in some cases, literature emission factors, depending on the pollutant and type of facility.

Once the point source inventory is completed, total utility fuel consumption for each province is reduced as appropriate and combined with typical fuel-based emission factors from the literature to estimate area source emissions.

Point Sources:
For all pollutants and combuster types, site-specific emissions data is the preferred emission estimation procedure. In the absence of site-specific

source test data, emission estimates should be based on a combination of site-specific data, material balance and literature- based emission factors.

Site-specific data required for each unit is as follows:

- unit type - internal, external; firing configuration; capacity; fuel
- fuel - consumption data; sulphur content (depends on fuel); ash content and handling/storage operations (if coal)
- control - type; rated efficiencies; tested efficiencies
- boiler ash - (see below)

$SO_x$ emissions for external combustion sources are best calculated using a mass balance approach which incorporates the following data:

- fuel consumption by fuel type for each boiler,
- weighted-average sulphur content of fuel used by fuel type and boiler,
- average factor for sulphur retention in boiler ash (e.g., average sulphur content in ESP ash).

In most cases, these data should be readily available on a monthly or annual basis. As an example, for a boiler burning 100,000 tonnes of 3% sulphur containing coal in which 2% of the sulphur is retained in the ash, the $SO_x$ emissions can be readily calculated by:

$$SO_x \text{ Emission} = 100{,}000 \times 0.03 \times 0.98 \times \frac{64}{32} = 5880 \text{ tonnes}$$

It should be noted that the residual sulphur content in ash of many New Brunswick and Nova Scotia coals is reported to be generally less than 2% on the basis of a relatively few number of analyses for each coal type. On the other hand, significant amounts of sulphur are retained in the ash of coals used in some Ontario Hydro generating stations (e.g., up to 17.5% sulphur retention). (Ontario Research Foundation 1987)

The $SO_x$ emissions estimated through this method should be verified by using the appropriate emission factors and control efficiencies in the literature. (U.S. EPA 1985 and U.S. EPA 1987)

In the absence of site-specific data, all other pollutant emission estimates ($SO_x$ for internal combusters, and $NO_x$, particulate matter, VOC and CO for all combusters) and particulate matter for coal handling emissions should be based on emission factors and control efficiencies as presented in AP-42 (U.S. EPA 1985) and the NAPAP emission factor listing (U.S. EPA 1987). It should be noted that the emission factors in the NAPAP report are uncontrolled. In some cases, site-specific control efficiency information for some or all of the pollutants may be available.

TSP emission factors for coal combustion are based on ash content of the coal. Coal combusters must also be inventoried for materials handling TSP emissions. Suitable emission factors are available in AP-42, under coal cleaning operations.

Area Sources:
Once the point source inventory is completed, emissions from remaining sites are calculated using the area source methodology. Fuel consumption for the sector is reduced appropriately to reflect fuel consumed by sites included in the point source inventory. Area source emissions are calculated using AP-42 emission factors and typical control efficiencies for each combuster type. (U.S. EPA 1985)

### e) Activity Level

Information on the location, size and fuel consumption of power generation plants can be obtained for each province from the following:

(a) Provincial Energy Ministry,
(b) Provincial Utility Commission,
(c) Public Utility Corporation.

Provincial statistics for fuel consumption can be found in Statistics Canada Report 57-003. For those sites meeting point source criteria, site contacts should be established to obtain the required detailed site information. (Edwards and Cotton 1988)

### f) Alternative Emission Estimation Procedures

Alternatives to site-specific emissions test data provided in the preferred emission estimation procedure (Section d), involved the use of emission factors provided in the literature. An alternative approach would be to take site-specific emission factors for one site and apply those factors to other similar sites, allowing for differences in fuel composition and/or control devices.

An alternative method of deriving (or confirming) fuel consumption data is to back-calculate from power output data by fuel type for a given area or point source. This method, which is described in Edwards and Cotton (1988), requires point or area specific data on power generation and operating hours.

### g) Temporal Variability

Most point-specific fuel consumption data should be available on a monthly basis. Provincial fuel consumption data from Statistics Canada is available on a quarterly basis. A report by MEP Company and Ontario Research Foundation provides further information on province-specific seasonal, daily and hourly temporal factors.

### h) Geographical Variability

Area source fuel combustion data is available on a provincial basis. Further geographical resolution would have to be obtained from the utilities.

### i) Point Source Establishments

Thermal power generation sources currently listed as point sources are summarized in Table B.49.1-1.

## TABLE B.49.1-1

### Thermal Power Generation - Environment Canada
### Point Source List - 1990
### (SIC 49110)

| Province | Plant ID | Plant Name | | Location | Principal Fuel |
|---|---|---|---|---|---|
| Newfoundland | 100005 | Nfld. and Lab. Power Co.<br>-Holyrood G.S. | | Holyrood | Residual Oil |
| | 100006 | Nfld. and Lab. Power Co.<br>St. John's Steam Plant | | St. John's | Residual Oil |
| Prince Edward | 110001 | Maritime Electric Co. Ltd. | | Charlottetown | Residual Oil |
| Nova Scotia | 120005 | N.S. Power Corp. | - Maccan River G.S. | Maccan | Bit. Coal |
| | 120006 | " " | - Glace Bay G.S. | Glace Bay | Bit. Coal |
| | 120007 | " " | - Trenton G.S. | Trenton | Bit. Coal |
| | 120013 | " " | - Tuft's Cove G.S. | Dartmouth | Residual Oil |
| | 120017 | " " | - LR Water St. G.S. | Halifax | Residual Oil |
| | 120020 | " " | - Point Tupper G.S. | Point Tupper | Residual Oil |
| | 120025 | " " | - Lingan G.S. | Lingan | Bit. Coal |
| New Brunswick | 130011 | N.B. Power Com. | - Grand Lakes G.S. | Minto | Bit.Coal |
| | 130013 | " " | - Courtenay Bay G.S. | Saint John | Residual Oil |
| | 130015 | " " | - Dalhousiee G.S. | Dalhousie | Bit. Coal |
| | 130016 | " " | - Coleson Cove G.S. | Saint John | Residual Oil |
| Ontario | 351043 | Ontario Hydro | - Lambton G.S. | Courtright | Bit. Coal |
| | 351112 | " " | - Nanticoke G.S. | Nanticoke | Bit. Coal |
| | 351282 | " " | - Lakeview G.S. | Mississauga | Bit. Coal |
| | 351357 | " " | - Thunder Bay G.S. | Thunder Bay | Lig/Bit. Coal |

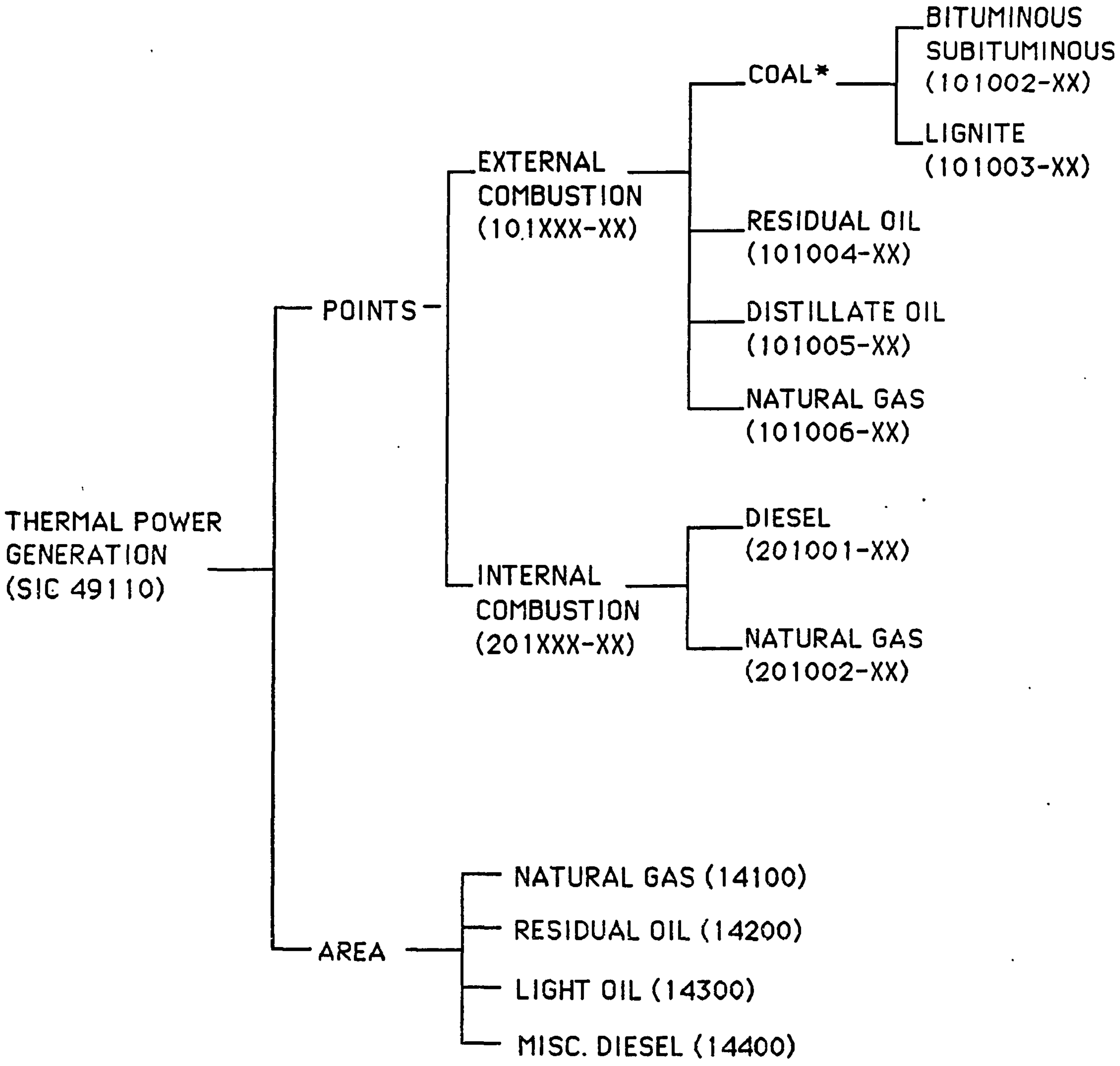
## TABLE B.49.1-1 (Contd.)

### Thermal Power Generation - Environment Canada
### Point Source List - 1990
### (SIC 49110)

| Province | Plant ID | Plant Name | Location | Principal Fuel |
|---|---|---|---|---|
| 351358 | | " " - Atikokan G.S. | Atikokan | Lignite Coal |
| Manitoba | 460012 | Manitoba Hydro - Brandon G.S. | Brandon | Lignite Coal |
| | 460013 | " " - Amy Street G.S. | Winnipeg | Lignite Coal |
| Saskatchewan | 470015 | Boundary Dam Power Plant | | |
| | 470016 | Sask. Power - Estevan Power Plant | | |
| | 470018 | Queen Elizabeth Power Plant | | |
| | 470043 | Sask. Power - Poplar River Power Plant | | |
| Alberta | 480105 | Alberta Power - H.R. Milner G.S. | Edmonton | |
| | 480166 | " " - Battle River G.S. | Edmonton | |
| | 480167 | " " - Palisades G.S. | Edmonton | |
| | 480168 | " " - Sheerness G.S. | Edmonton | |
| | 480169 | Medicine Hat Power | Medicine Hat | |
| | 480107 | Edmonton Power - Rossdale G.S. | Edmonton | |
| | 480017 | Transalta Utilities Corp. | Calgary | |
| | 480018 | " " " | Calgary | |
| | 480170 | " " " | Calgary | |
| | 480171 | Dept. of Physics, Univ. of Alberta | Edmonton | |

Figure B.49.1-1

THERMAL POWER GENERATION SCCS



*COAL-FUELED POINT SOURCES MUST INVENTORY MATERIALS HANDLING AS WELL AS COMBUSTION EMISSIONS

## References - Section B.49.1

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Manual". Prepared for Environment Canada, Environmental Analysis Branch.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for the 1980 National Anthropogenic Area Source Emissions. Volume 1: Report. Volume II: Appendix". Prepared for Environment Canada.

Ontario Research Foundation, 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Prepared for Environment Canada, Environmental and Chemical Engineering Division.

Shih, C.C., Hamersma, J.W., Ackerman, D.G., Beimer, R.G., Kraft, M.L. and Yamada, M.M. 1979. "Emissions Assessment of Conventional Stationary Combustion Systems: Volume II. Internal Combustion Sources". Prepared for the U.S. Environmental Protection Agency. EPA/600-13, PB-296 390.

Shih, C.C., Orsini, R.A., Ackerman, D.G., Moreno, R., Moon, E.L., Scinto, L.L. and Yu, C., 1980. "Emissions Assessment of Conventional Stationary Combustion Systems: Volume III. External Combustion Sources for Electricity Generation". EPA-600/7-81-003a.

Statistics Canada, "Quarterly Report on Energy Supply-Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutants Emission Factors. Vol. I: Stationary Point and Area Sources". AP-42, 4th Edition (and Supplements A and B). U.S. Environmental Protection Agency, Research Triangle Park, N.C.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emissions for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corp. for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, N.C.

# B.56.1 RESIDENTIAL FUEL COMBUSTION (SIC 56221)

## a) General Description

This sector includes the residential use of natural gas, natural gas liquids, kerosene and stove oil, coal, distillate oil and residual oil. Residential wood combustion is discussed in Section B.56.4.

Particulate matter, $SO_2$, $NO_x$, CO and VOCs are all emitted as a result of residential fuel combustion.

## b) Sector Description

Residential fuel combustion is coded under the following SCCs:

| SCC | Description | | |
|---|---|---|---|
| 11100 | Residential Fuel Combustion | - | Natural Gas |
| 11200 | Residential Fuel Combustion | - | Natural Gas Liquids |
| 11300 | Residential Fuel Combustion | - | Kerosene and Stove Oil |
| 11400 | Residential Fuel Combustion | - | Coal |
| 11500 | Residential Fuel Combustion | - | Distillate Oil |
| 11600 | Residential Fuel Combustion | - | Residual Oil |

Distillate oil and gas-fired residential furnaces have numerous burner configurations, designed to try to optimize the efficiency of fuel combustion. In natural gas-fired units the fuel is usually premixed with excess air (commonly 10 to 15 percent) prior to injection in the burner to increase combustion efficiency. Distillate oil-fired units may use pressure or vaporization to atomize fuel oil. This produces finer droplets for combustion, which usually increases combustion efficiency and decreases the formation of pollutants. Residual oil has little use in domestic applications, as it must be heated to facilitate handling and proper atomization (U.S. EPA 1985, U.S. EPA 1987a).

Residential coal-fired furnaces are usually underfeed or hand-stoked units. Boilers, used for steam or hot water production, and warm-air furnaces are usually stoker fed and automatically controlled by a thermostat. These are usually designed for a specific type of coal. Other hand-fed residential coal combusters, usually used for auxiliary heating, include room heaters, metal stoves and metal and masonry fireplaces. The majority of the coal burned for this purpose is bituminous or anthracite coal; lignite coal is an insignificant portion of the total. (U.S. EPA 1987a, DeAngelis and Reznik 1979).

Residential combustion units do not usually have particulate or gaseous pollutant devices. However, proper design, use and maintenance of each unit can decrease the emissions. These involve changes in fuel properties (i.e., cleaning coal), fuel type, firing rate, firing equipment design, modified combustion air flow control, better thermal control and heat storage and the cyclic operation of automatic equipment. (U.S. EPA 1987a, DeAngelis and Reznik 1979)

### c) Inventory Approach

Residential fuel combustion is inventoried as an area source, using fuel-based emission factors for each pollutant type and activity levels in terms of fuel consumption.

### d) Preferred Emission Estimation Procedure

Particulate matter, $SO_2$, CO, $NO_x$ (as $NO_2$), HC (non methane VOCs) (and in some cases THC) emission factors suitable for residential fuel combustion are listed, by fuel type, in AP-42 (U.S. EPA 1985), under the following descriptors:

coal - hand-fired units (by type of coal)
distillate oil - residential furnaces
residual oil - commercial boilers
kerosene and stove oil - use distillate oil
natural gas - domestic and commercial boilers
natural gas liquids - liquified petroleum gas, domestic

Most $SO_2$ emission factors depend on the sulphur content of the fuel. This information can be obtained from the Inventory Management Division of Environment Canada.

The TSP emission factor for particulate has been updated for commercial residual oil fuel use (which is used for residential residual oil fuel use - see above) for the 1985 NAPAP emissions inventory (U.S. EPA1987b).

### e) Activity Level

Provincial quarterly residential fuel consumption data is reported by Statistics Canada in Publication No. 53-007. Distillate oil is listed as light fuel oil. Residual oil is listed as heavy fuel oil. Environment Canada currently includes agricultural residual oil use with residential residual oil use, and inventories the total as residential residual oil combustion. This report also provides details on the type of coal burned residentially by province.

More detailed regional fuel combustion statistics may be available from provincial ministries.

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Provincial fuel combustion data (see section e)) are provided on a quarterly basis. Seasonal, daily and hourly temporal factors are discussed in a report by The MEP Company and Ontario Research Foundation (1985). Heating degree-day data could alternately be used to develop more detailed temporal factors.

### h) Geographical Variability

Fuel combustion data are provided on a provincial basis, or may be available on a regional basis (see section e)). Population data, residential housing unit information or heating degree-days data could be used to further apportion this data.

## References - Section B.56.1

DeAngelis, D.G. and Reznik, R.B., 1979. "Source Assessment: Residential Combustion of Coal". EPA-600/2-79-019a. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Statistics Canada, "Quarterly Report on Energy Supply - Demand, Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Vol. I: Stationary Point and Area Sources". AP-42, 4th Edition (and Supplements A and B). Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Locating and Estimating Air Emissions from Sources of Polycyclic Organic Matter (POM)". EPA-450/4-84-007p. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987b. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by the Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## B.56.2 COMMERCIAL/INSTITUTIONAL FUEL COMBUSTION (SIC 56222)

### a) General Description

This category includes external combustion sources used for space/water heating in commercial establishments, health and educational institutions and government/public administration facilities. Internal combustion sources used by this sector (primarily oil-fired reciprocating engines used for pumping water and sewage) are included in off-road use of diesel (SIC 45602).

Particulate matter, $SO_2$, CO, $NO_x$ and VOCs are all emitted from commercial/institutional fuel combustors.

### b) Sector Description

Commercial/institutional external combustion sources may be classified by the boiler/furnace design or type of fuel. Further characterizations include installed capacity and firing method. Smaller units (<13.2 J/hr) are typically cast iron or firetube units. Watertube units constitute 100 percent of all units above 50 x $10^9$ J/hr. (Suprenant et al 1981)

Possible fuel types include coal, distillate oil, residual oil, kerosene and stove oil, liquid petroleum gases and natural gas. Natural gas and petroleum products represented almost 100% of the energy consumption in this sector for Canada. (Ontario Research Foundation 1983)

Air pollution control equipment is usually not installed on commercial/institutional combustion units. Some of the larger units, particularly the coal-fired boilers (pulverized or stoker) do have controls. These have automated particulate control efficiencies of 40% for pulverized units (primarily dry bottom) and 20% for all stokers, based on data in the U.S. NEDS system. Gas and oil-fired units are usually uncontrolled, although proper equipment selection, maintenance and operating practices can be used to limit emissions. (Suprenant et al 1981)

The following SCCs are used to inventory commercial/institutional fuel combustion:

| SCC | Description | | |
|---|---|---|---|
| 12100 | Commercial/Institutional | - | Natural Gas |
| 12200 | " | - | Liquid Petroleum Gases |
| 12300 | " | - | Kerosene and Stove Oil |
| 12400 | " | - | Coal |
| 12510 | " | - | Distillate Oil |
| 12520 | " | - | Residual Oil |

## c) Inventory Approach

Emissions from commercial/institutional fuel combustion are inventoried as area sources, using fuel-based emission factors and activity levels by fuel type.

## d) Preferred Emission Estimation Procedure

Particulate matter, $SO_2$, CO, $NO_x$ (as $NO_2$) and HC (non-methane VOCs) (and in some cases THC) emission factors suitable for commercial/ institutional fuel combustion are listed, by fuel type, in AP-42 (U.S. EPA 1985) under the following descriptors:

coal - depends on firing type and type of coal
distillate oil - commercial
residual oil - commercial
natural gas - commercial
natural gas liquids - liquified petroleum gas, commercial
kerosene and stove oil - use emission factors for distillate oil

Most $SO_2$ emission factors depend on the sulphur content of the fuel. This information can be obtained from Environment Canada. If no information is available for coal, hand-stoked bituminous coal-fired boiler emission factors should be chosen.

Some of these emission factors were updated for the 1985 NAPAP inventory. These are listed in U.S. EPA (1987) under SCC 1-03.XXX-XX, along with notes for the basis of these changes.

### e) Activity Level

Provincial quarterly fuel combustion is reported by Statistics Canada in Publication No. 53-007 under commercial (and other institutions) and public administration. These should be combined for this sector. More detailed regional fuel combustion information may also be available from provincial ministries.

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Fuel combustion data (see section e) are provided on a quarterly basis. Seasonal, daily and hourly temporal factors are discussed in a report by The MEP Company and Ontario Research Foundation (1985).

### h) Geographical Variability

Fuel combustion data (see section e) are provided on a provincial (or possibly regional) basis. Commercial labour force or population data could be used to further apportion this data.

## References - Section B.56.2

The MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Statistics Canada, "Quarterly Report on Energy Supply - Demand". Publication No. 57-003.

Suprenant, N.F., Hung, P., Li, R., McGregor, K.T., Piispanen, W. and Sandberg, W.S., 1981. "Emissions Assessment of Conventional Stationary Combustion Systems. Volume IV: Commercial/Institutional Combustion Reports". Prepared for the U.S. Environmental Agency. EPA-600/7-81-003b, PB 81 145 187, U.S. EPA, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutants Emission Factors. Volume I: Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## B.56.3 INDUSTRIAL FUEL COMBUSTION (SIC 56223)

### a) General Description

Stationary external combustion sources are primarily used in industry for the generation of process steam and space heating. Some units are also used for electricity generation. Fuels discussed in this sector include natural gas, natural gas liquids, kerosene and stove oil, coal, residual oil and distillate oil.

Emissions due to the industrial combustion of coke and wood (usually wood wastes) are currently inventoried as part of process emissions. Coke is primarily used in the iron and steel production, smelting and petroleum refining industries. Wood is primarily used as a fuel in the wood and pulping industries.

Internal combustion units used in industry are inventoried under SIC 45602 (off-road diesel engines).

Emissions of particulate matter, $SO_2$, $NO_x$, CO and VOCs are inventoried for this sector. Coal and distillate oil-fired industrial combustors are significant sources of $SO_2$, $NO_x$ and TSP. Natural gas-fired combustors also emit significant amounts of $NO_x$.

### b) Sector Description

Industrial external combustion stationary sources are inventoried under the following SCCs:

| SCC | Description | | |
|---|---|---|---|
| 13100 | Fuel Combustion - Stationary Source - Industrial | - | Natural Gas |
| 13200 | " " " " " | - | Natural Gas Liquids |
| 13300 | " " " " " | - | Kerosene and Stove Oils |
| 13400 | " " " " " | - | Coal |
| 13510 | " " " " " | - | Distillate Oil |
| 13520 | " " " " " | - | Residual Oil |

Bituminous dry-pulverized and spreader stoker coal-fired units are the most common large-sized coal-fired unit, while smaller needs are more commonly met with underfeed and overfeed stokers. Lignite and anthracite coal are usually burned in stokers. Oil and natural gas burning units are usually watertube or firetube boilers. Further details on all of these systems are available in the literature. (Suprenant et al 1981, U.S. EPA 1985 and 1987a)

Emissions control on industrial boilers is mainly directed at reducing particulate flue gas emissions from coal-fired boilers. This is achieved by using baghouses, ESPs, wet scrubbers and multicyclones. Flue gas desulphurization (FGD) units for $SO_2$ control are much less common in industrial coal-fired units than in the utility sector, but are used. $SO_2$ control is more commonly achieved through the use of low sulphur coal. (Suprenant et al 1981, U.S. EPA 1987a)

Particulate emissions from oil-fired industrial combustors are usually not controlled. Any units with potentially excessive $SO_2$ emissions usually switch to low sulfur oils rather than install emission controls. Natural gas units also do not usually have any sort of emissions control. (U.S. EPA 1987a)

### c) Inventory Approach

Industrial fuel combustors are inventoried as area sources, using emission factors based on fuel consumption rates.

Fuel combustion by industry is a particularly important source of criteria pollutant emissions, but in defining the contribution from this sector, it is difficult to eliminate duplication of emissions in area and point source inventories. For example, if point source emission measurements are conducted on an operation where criteria pollutants are emitted from both fuel burning and process material, and the fuel contribution is not deducted in source test data (or emission factors), then emissions from such operations would be duplicated when calculating industrial fuel consumption.

There are also industries for which the use of emission factors attributable to general industrial fuel uses would result in overestimation of emissions. For instance, if emitted sulphur oxides from fuel are actually adsorbed by materials in various types of kilns (e.g., lime and cement), then industrial fuel consumption emission factors overestimate sulphur dioxide emissions for any fuel used in these kilns. This is because the emission factors are based on the assumption that practically all fuel sulphur is released during combustion.

For these reasons, it is recommended that industrial use of natural gas, coal and residual and distillate oil by the following sectors be inventoried as part of that sector's criteria pollutant emissions:

Pulp and Paper Industry
Cement Manufacturing
Lime Manufacturing

Since available provincial industrial fuel use totals currently include fuel use by these sectors, care must be taken to subtract their consumption from the totals.

There are also certain sectors not included in provincial industrial fuel use totals. These, which are also inventoried separately, all involve energy producer consumption:

| | |
|---|---|
| coal cleaning: | coal consumption |
| petroleum refining: | crude oil and refined petroleum products |
| natural gas production: | natural gas |

In some cases, specific point information may be available to characterize industrial fuel combustion emissions. If this point is inventoried separately under the appropriate SCC 1-02-XXX-XX (see U.S. EPA 1987b), the fuel consumption must be subtracted from fuel use totals used for the area source emission estimates.

## d) Preferred Emission Estimation Procedure

The following references are recommended for use in the development of an area source industrial fuel use emissions inventory:

| | | |
|---|---|---|
| U.S. EPA 1987b | - | a detailed listing of criteria pollutant emission factors used in the 1985 NAPAP inventory by fuel firing rate or configuration or fuel grade. |
| | - | all emission factors are uncontrolled. |
| U.S EPA 1985 | - | the basis for many of the factors provided in U.S. EPA 1987b is given in this report, along with a summary of currently available information on emissions control efficiencies. |

Industrial fuel external combustion emission factors are listed by fuel type in the detailed NAPAP Emission Factor listing under SCC 1-02-XXX-XX, by firing rates, firing configuration or fuel grade (as appropriate to the fuel type). To properly conduct a criteria pollutant emission inventory it would be necessary to resolve provincial fuel consumption data into these sub-categories for each type of fuel. However, this is just not possible with the currently available data base on industrial boiler configurations, firing rates and fuel consumption. Therefore, it is necessary to choose representative emission factors for each type of fuel. The following strategy is recommended:

| | | |
|---|---|---|
| coal | - | the preferred method for emission factor derivation would be to survey the industrial coal users for boiler, emissions control and coal (type, ash content and sulphur content) data. Failing this, the use of emission factors for uncontrolled spreader stokers, or an average overall stoker configuration, for each coal type could be used. |

all other fuels - an average of all available fuel-specific
emission factors is recommended.

Information on coal ash and sulphur content is available. Typical distillate and residual oil sulphur contents are summarized in a recent Environment Canada report (RTM Engineering 1988).

### e) **Activity Level**

The basic approach to estimating industrial external combustion fuel consumption by fuel type was outlined in section c) (Inventory Approach). Statistics Canada produces quarterly statistics on provincial fuel use (Statistics Canada n.d.). For each fuel type, the total industrial fuel use should be used, <u>less</u> the following:

- cement industry consumption (in the same report)
- pulp and paper consumption (must be obtained from industry)
- lime manufacturing (must be obtained from industry)

Note that <u>all</u> diesel fuel oil is assumed to be used in vehicles, on or off-road, or in thermal power generation.

Producer consumption is not included in the industrial use totals, and so does not need to be deducted.

### f) **Alternative Emission Estimation Procedure**

Although alternative data sources are available for some of the activity level data required, the Statistics Canada Energy Consumption Data is considered to be the best and most self-consistent data base available for activity level derivation at this time. Therefore, currently available alternative data sources are not recommended unless the user intends to use this data to inventory certain industrial fuel combusters as point sources. If this is the case, care must be taken to deduct point source fuel consumption from the area source totals, as appropriate. Point source industrial combusters should be assigned SCCs as listed in the NAPAP

Emission Factor Listing under 1-02-XXX-XX (U.S. EPA 1987b). In the absence of source-specific emission data, emission factors should be chosen for each point based on fuel type, consumption data, boiler information and details on emissions control.

### g) Temporal Variability

Hourly, daily and seasonal temporal factors are available in a report by MEP Company and Ontario Research Foundation (1985). Activity level data are also available on a quarterly basis.

### h) Geographical Variability

Activity level data are available on a provincial basis. Further geographical apportionment could be done using industrial labour force data available from Environment Canada.

## References - Section B.56.3

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for the 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

RTM Engineering Ltd., 1988. "Review of Sulphur Content of Petroleum and Synthetic Fuels, 1978-1987". Prepared for Environment Canada.

Statistics Canada, "Quarterly Report on Energy Supply-Demand". Publication No. 57-003.

Suprenant, N.F., Battye, W., Roeck, D. and Sandberg, S.H., 1981. "Emissions Assessment of Conventional Stationary Combustion Systems: Vol. V. Industrial Combustion Sources". Prepared for the U.S. Environmental Protection Agency, EPA-600/7-81-003c. U.S. Environmental Protection Agency, Research Triangle Park, N.C.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutants Emission Factors. Vol. I: Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). U.S. Environmental Protection Agency, Research Triangle Park, N.C.

U.S. Environmental Protection Agency (U.Ω. EPA), 1987a. "Locating and Estimating Air Emissions from Sources of Polycyclic Organic Matter (POM)". EPA-450/4-84-007p. U.S. Environmental Protection Agency, Research Triangle Park, N.C.

U.S. Environmental Protection Agency (U.S. EPA), 1987b. "Criteria Pollutant Emissions for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, N.C.

## B.56.4 RESIDENTIAL WOOD COMBUSTION (SIC 56224)

### a) General Description

There are three types of residential wood combustors: stoves (conventional and slow combustion), fireplaces and furnaces.

Emissions of particulate matter, CO, $NO_x$, $SO_x$ and VOC are all inventoried for residential combustion. VOC and particulate matter from these sources form a significant portion of Canadian emissions.

### b) Sector Description

Residential wood combustors are coded under the following SCC's:

| SCC | Description | | |
|---|---|---|---|
| 11610 | Residential Wood Combustion | - | Conventional Stove |
| 11620 | Residential Wood Combustion | - | Slow Combustion Stove |
| 11630 | Residential Wood Combustion | - | Fireplace |
| 11640 | Residential Wood Combustion | - | Furnace |

Residential wood stoves are primarily used as space heaters to supplement conventional heating systems. Commonly made of cast iron, heavy gauge sheet metal and/or stainless steel, there are two main types of wood stoves. Radiating wood stoves transfer heat by radiation from the hot stove walls to the room. Circulating stoves have double wall construction with louvers on the exterior wall. This allows the conversion of radiant energy to warm convection air. The degree of combustion and heat transfer for both types of stoves largely depends on the firebox temperature, residence time and turbulence (mixing). Many stoves have internal baffles which promote heat transfer by increasing the residence time of flue gases. The use of baffles and pre-heated secondary combustion air helps to reduce emissions by promoting mixing and more thorough combustion. (U.S. EPA 1985)

Emissions control for wood stoves may be accomplished in two main ways: operating practices and modified stove design. Operating practices include fuel selection, size, moisture content, feed rate, combustion air supply and equipment maintenance. Design modifications attempt to either reduce pollutant formation in the fuel magazine and/or primary combustion zone or destroy pollutants in the primary or a secondary combustion zone. Catalytic converters, similar to those used in automobiles, are under development for emissions control, but there are difficulties with safely achieving adequate catalyst operating temperatures and there are indications that under certain conditions some emissions are increased with these devices. (U.S. EPA 1985)

There are two main types of fireplaces. Masonry fireplaces, which are built in-place, typically have large fixed openings to the firebed. Dampers above the firebed limit heat losses when the fireplace is not in use. Some of these fireplaces are designed or retrofitted with doors and louvers to reduce the intake of combustion air during use. Prefabricated fireplaces may be freestanding or "zero-clearance". Both types are commonly equipped with louvers and glass doors to reduce the intake of combustion air. Some are surrounded by ducts through which floor level air is drawn by natural convection and is returned to the room after heating. (U.S. EPA 1985)

No emissions control devices are available for fireplaces. Fireplace design can reduce emissions by promoting a fast burn rate and higher flame intensity, thereby enhancing secondary combustion. (U.S. EPA 1985)

### c) Inventory Approach

Residential wood combustion is inventoried as an area source, using fuel-based emission factors and activity levels for each type of combustor.

## d) Preferred Emission Estimation Procedure

Emission factors recommended by Environment Canada for residential wood combustors are presented in Table B.56.4-1. These were based on an internal Environment Canada report from Envirobec (1983), with the exception of THC and VOC emission factors.

VOC emissions generated from fuel wood combustion have recently come under close scrutiny in the U.S. and numerous studies have been conducted in recent years. Unfortunately, a clear consensus on typical emission factors for this source have yet to be established. For example, a review of several recent reports on VOC emission rates from fireplaces indicate factors ranging from 1.0 to 15.0 kg/tonne of fuel wood combusted. Discrepancies in these reports regarding total hydrocarbon versus non-methane emissions and dry versus wet fuel basis may account for some variations. (Edwards and Cotton 1988)

Environment Canada currently uses THC and VOC emission factors reported in AP-42 (U.S. EPA 1985) for stoves (conventional and slow combustion) and fireplaces. All emission factors for furnaces are taken from emission factors for commercial wood-burning space heaters (U.S. EPA 1987), as listed under SCC 1-05-002-09.

## e) Activity Level

Fuelwood consumption by province is published in Statistics Canada report number 25-201.

An internal study by Environment Canada (1983) estimated the following utilization breakdown (based on the quantity of wood burned):

| | |
|---|---|
| Slow combustion stove | 11.8% |
| Conventional stove | 24.3% |
| Fireplace | 47.5% |
| Furnace | 16.4% |

These numbers can be used to break down the total wood burned into the different combustor types.

### f) Alternative Emission Estimation Procedure

### g) Temporal Variability

Seasonal, daily and hourly temporal factors for residential fuelwood combustion are discussed in a report by the MEP Company and Ontario Research Foundation (1985).

### h) Geographical Variability

Fuelwood combustion data is available on a provincial basis (see section e)). Population could be used to further spatially allocate this consumption data.

## TABLE B.56.4-1

## Environment Canada
## Residential Wood Combustion Emission Factors
## (g/kg (wet basis) wood burned)

| Pollutants | Conventional Stove | Slow Combustion Stove | Fireplace | Furnace |
|---|---|---|---|---|
| Particulates | 33.0[a] | 25.0[a] | 25.0[a] | 10.0 |
| CO | 110.0[a] | 175.0[a] | 90.0[a] | 60.0 |
| $NO_x$ | 0.5[a] | 0.5[a] | 0.5[a] | 2.0 |
| $SO_x$ | 0.8[a] | 0.8[a] | 0.8[a] | 0.8 |
| VOC | 20.0[b,c] | 51.0[b] | 13.0[b] | 0.7 |
| THC | 20.2[b,c] | 51.5[b] | 13.0[b] | 0.9 |

Notes:

a. Based on Environment Canada 1983.

b. Based on AP-42 (U.S. EPA 1985).

c. The emission factors for conventional stoves were assumed to be 40 percent of those reported for slow combustion stoves.

d. Based on SCC 1-05-002-09 from U.S. EPA (1987).

## References - Section B.56.4

Environment Canada, 1983. "Quantification et Prévision des Emissions Provenant du Chauffage Résidential au Bois au Québec". Prepared by Roche Envirobec for Environment Canada, internal report.

The MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

Statistics Canada "Logging", Publication 25-201.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Vol. I: Stationary Point and Area Sources". AP-42, 4th Edition (and Supplements A and B). Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory". Prepared by Radian Corporation for the U.S. Environmental Protection Agency. EPA-600/7-87-015. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

## C.04.1 WIGWAM BURNERS (SIC 04111)

### a) General Description

Wigwam or conical burners, associated with the lumber, plywood and other forest product mills, are used in some remote areas to dispose of wood wastes such as sawdust, bark and other wood residues. Some of these wastes may be burned in boilers to generate power at the sawmill or transported to nearby pulp and paper mills, where feasible, for fuel combustion in boilers. Although few measurements are available, significant emissions of all the common air pollutants are suspected and are included in inventories.

### b) Process Description

Conical (Wigwam or Tee Pee) Burner (SCC 32100):
Wigwam burners are a truncated metal cone with a screened top vent in which the wood refuse is burned on a raised grate. Air is blown below the grate and above the fuel pile to maintain combustion of the wood refuse without supplementary fuel. Due to the generally poor combustion conditions (e.g., excessive air and low temperature), associated with often poorly maintained shells, such facilities might be expected to represent significant sources of combustible pollutants such as smoke, CO and hydrocarbons (Environment Canada 1976, U.S. EPA 1985). The extent of pollutant control has not been recently documented, but most are presumed to be uncontrolled.

### c) Inventory Approach

Area source methods are normally used to inventory wigwam burner emissions, since there is little information on record for the extent of their use and amounts of wood waste burned. In this regard, it is possible that some emissions from individual units may exceed 100 tonnes/year. Reported emission factors are available, in order to estimate emissions after base quantities have been estimated.

## d) Preferred Emission Estimation Procedure

Uncontrolled emission factors expressed in kg emission/tonne of wood waste burned (at 50% moisture), are available in the following reports:

- AP-42 (U.S. EPA 1985),
- factors reported for the NAPAP emission inventory (U.S. EPA 1987).

The emission factors are the same in both reports, except that particulate emission factors presented in AP-42 provide an option to use different factors depending on the burner maintenance (i.e., extent of excess air). These have also been applied to wigwam burners that are, in part, compiled as point sources in U.S.inventories (SCC 5-03-001-05). Derivation of wood waste quantities incinerated in wigwam burners represents the largest uncertainty in compiling emissions as noted below.

## e) Activity Level

Data on the quantity of wood refuse incinerated should preferably be obtained from the Ministry of the Environment in each province or Regional Offices with specific information acquired through contact with selected sawmills (i.e., to define typical wood waste utilization or disposal options). As a guide, earlier reported data for British Columbia and Manitoba indicated typical sawdust disposal methods by saw and planing mills to be: 45% used for energy, 40% incinerated, 12% landfilled and 3% for other purposes (Beak Consultants 1976, Ondro et al 1980). Similarly, it is reported that operations with wigwam burners may incinerate from 10 to 100 tons per day of wood waste depending on the size of the burner and other factors.

It is also suggested to use other information in an effort to verify or estimate base quantities as discussed in other reports (Environment Canada 1983, ORF/MEP 1983, Edwards and Cotton 1988). For example, provincial statistics are available on the volume of products (i.e., lumber and plywood) produced at wood-related industries (Statistics Canada) and

Environment Canada have derived an estimate of the amount of wood waste burned relative to production (Environment Canada 1975 and unpublished data). With a known wood waste generation factor, the quantity of refuse generated at such industries can be estimated (Edwards and Cotton 1988) by:

$$\text{Weight of Refuse Incinerated. @ 50\% MC} = \frac{m^3\,\text{product}}{\text{year}} \times \frac{m^3\,\text{refuse}}{m^3\,\text{product}} \times \text{density kg/m}^3$$

where the density is for the fuel as burned (typically 45-50% moisture content as burned) (U.S. EPA 1985).

However, this can be expected to overestimate emissions for some facilities, since a significant portion of wood waste is utilized for other purposes when facilities are located near pulp mills. Thus, total amounts of lumber produced at sawmills located at a distance from pulp and paper mills (e.g., 80 to 100 km or greater), in conjunction with wood waste generation factors relative to the products and the above equation, may provide a better estimate of wood wastes actually incinerated by wigwam burners (Edwards and Cotton 1988). The actual lumber mill locations can be obtained from Scott's Directory, but an estimate would be required on the fraction of lumber produced at facilities distant from pulp mills, to deduct from provincial statistics (e.g., perhaps by number of employees at the sawmills). The emission factors can then be applied to the base quantities determined, in order to estimate wigwam burner emissions.

### f) Alternative Emission Estimation Procedures

Alternative methods of estimating wigwam burner emissions have been reported by B.H. Levelton and Associates (Edwards and Cotton 1988), based upon specific assumptions of gas generation rates by wood burning in conjunction with air emission permit data for each facility using a wigwam burner.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors have been developed for wigwam burner emissions (MEP/ORF 1985), based on sawmill production statistics and typical operating schedules.

### h) Geographical Variability

Provincial lumber production data are reported by Statistics Canada for spatial apportionment of emissions to provinces. Similarly, the locations of saw and planing mills are available in the Scott Directory with which to geographically apportion wigwam burner emissions within a province. This has been done for Ontario in an earlier study (ORF/MEP 1983).

## References - Section C.04.1

Beak Consultants Ltd., 1978. "Technical, Economic and Environmental Aspects of Wet and Dry Debarking". Report EPS 3-WP-78-3. Prepared for Water Pollution Control Directorate, Environment Canada.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Report prepared for Environment Canada, Environmental Analysis Branch.

Environment Canada, 1975. "Combustion Technology for the Disposal and Utilization of Wood Residue". Report EPS 3-AP-75-4.

Environment Canada, 1976. "Advances in Small-Scale Refuse Incinerators - Seminar Proceedings". Solid Waste Management Branch Report EPS-3-EC-76-10, Environmental Conservation Directorate.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP083-10.

Environment Canada. Unpublished information. Combustion Sources Division.

MEP Company and Ontario Research Foundation (MEP/ORF), 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Report prepared for Inventory Management Division, xEnvironment Canada.

Ondro W.J., 1980. "A Directory of Primary Wood-Using Industries in Manitoba, 1980". Report NOR-X-230. Prepared by Canadian Forestry Service.

Ontario Research Foundation and MEP Company (ORF/MEP), 1983. "Area Source Emission Inventory of Nitrogen Oxides in Ontario". Report P-4162/G prepared for the Ontario Ministry of the Environment.

Statistics Canada. "Canadian Forestry Statistics". Publication No. 25-202.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors - AP-42". 4th Edition.

U.S. Environmental Protection Agency (U.S. EPA), 1987. "Criteria Pollutant Emission Factors for the NAPAP Emissions Inventory". Report prepared by Radian Corp. EPA/600/7-87/015.

## C.49.1 MUNICIPAL WASTE INCINERATION (SIC 49990)

### a) General Description

Centralized MSW incinerators to combust refuse are operated by municipal governments in a few Canadian communities, in order to reduce waste volumes and sometimes recover energy, as an alternative to waste disposal in landfills. It has been estimated that municipal refuse, comprising mainly non-hazardous solid and liquid materials, is generated at a per capita rate of 1.8 kg/day (Klicius 1987) and household refuse typically comprises 25-50% paper, 10-50% food waste, wood and other organic materials, 3-10% metals, 3-9% glass and 7-25% other non-combustibles (Alter 1987, Ozvacic et al 1985). Municipal incinerators, of varying designs and configurations, normally have burning capacities in excess of 50 tonnes refuse per day and large units may incinerate waste up to 1,000 tonnes/day (U.S. EPA 1988). All of the common gaseous and particulate pollutants are emitted during MSW combustion with the extent depending on factors such as: the composition of the refuse being burned, the type and operating conditions of the incinerator, as well as the type and removal efficiencies of installed control devices. The potential exists for significant particulate emissions due to the turbulence of combustion gases in contact with ash and condensation of metals after combustion. Intermediate products of incomplete combustion such as CO, VOC and other toxic chemicals might also occur under improper operating conditions.

### b) Process Description

Mass Burn (Multiple or Single Chamber) Incinerators (SCC 5-01-001-01 and 02):
Mass burn facilities are used most extensively to incinerate unprocessed wastes in multiple, dual or single chambers (U.S. EPA 1988 and 1989). Such facilities exist in Quebec, Ontario and British Columbia. In the older refractory-wall incinerators, waste enters by batch or continuous feed and moves through the chambers by travelling, rocking or reciprocating grate

systems. Both retrofitted or modern water-walled mass burn units, that currently operate in Canada and the U.S., utilize gravity or hydraulic ram feeders and reciprocating grates to move uncompressed refuse through the combustion chambers. After a drying zone, refuse is burned in the first chamber with the use of under and overfire air and final gas-phase combustion occurs in the second chamber. Auxiliary oil burners are used, when necessary, and most recover energy in the form of steam. Particulate emissions from the larger units are controlled by ESPs and fabric filters, that may be combined with dry scrubbing systems (e.g., dry sorbent injection or spray drying) to remove acid gases, while some older units use wet scrubbers. A facility in Quebec is controlled with a combination of ESP, dry lime scrubbing and a baghouse.

Controlled Air/Modular Incinerators (SCC 5-01-001-XX):
Modular combustors are classified according to either the starved-air or excess-air designs and have several common features (U.S. EPA 1989). They are often small batch-fed units operated without waste pre-processing and consist of two refractory-lined chambers which retain the waste for extended burning periods. Depending on the design, air is introduced to the primary chamber in either excess amounts, as in conventional mass burn facilities, or below stoichiometric requirements and subsequently controlled in the secondary chamber in order to achieve efficient combustion. Most starved-air units use auxiliary fuel burners for startup or maintaining temperature in both chambers when necessary and some use heat recovery boilers. Emission control devices are not normally used on modular incinerators since controlled air injection tends to minimize particulate carryover from the primary chamber. A two-chamber starved-air modular MSW incinerator operates in Prince Edward Island.

Refuse-Derived Fuel-Fired Combustors (SCC 5-01-001-XX):
RDF combustors burn processed solid municipal wastes that may vary from shredded waste as a primary fuel to finely divided waste fuel or pellets suitable for co-firing with other fossil fuels (U.S. EPA 1989). Such facilities usually recover heat from the boiler for producing steam or electricity. Emissions are normally controlled by ESPs which may be

combined with spray dryer systems for acid gas control. One RDF facility operating in Ontario is controlled by a dry lime scrubber and baghouse.

Pit or Trench Incinerators (SCC 5-01-005-10 to 12):
A relatively small amount of MSW waste is infrequently burned in pit incinerators or trench combustors in Canada (EPS 1978, Edwards and Cotton 1988), whereby combustion air is supplied at the top of the pit and directed to provide an air curtain. No pollution control equipment is used.

## c) Inventory Approach

Point source methods should be used to compile air pollutant emissions from municipal solid waste incinerators since a limited number of MSW facilities exist in Canada and emissions can be significant. Similarly, in several instances, facility-specific emission data can be determined for some units that have been tested under a variety of conditions in several studies. Reported emission factors, pertinent to all of the common air pollutants, are also available for specific types of incinerators and control devices with which to supplement or check emissions data where necessary.

## d) Preferred Emission Estimation Procedure

Information sources that can be used to check or calculate emissions for each of the pollutants include:

- Environment Canada (NITEP) source test data at specific facilities (Hay et al 1986, EPS 1985, EPS 1988) and other source test data (Thorndyke 1988),
- published and unpublished Environment Canada reports (Environment Canada 1983, Edwards and Cotton 1988),
- uncontrolled and controlled emission factors in AP-42 (U.S. EPA 1988),
- uncontrolled emission factors developed for the NAPAP inventory (U.S. EPA 1987).

It is recommended to use source-specific emissions test data for Canadian facilities where tests have been conducted (EPS 1985, EPS 1988, Thorndyke 1988) in preference to emission factors. However, more recent emission test measurements should be used, where available, in order to update existing data for some pollutants. These reported measurements provide either direct emission factors for some pollutants (e.g., particulate matter), in conjunction with feed rates at the time of measurements, and/or plant-specific emission factors can be derived from reported concentration information (e.g., other gaseous pollutants).

Where test data are not available, emission factors reported in AP-42 for the three common types of incinerators (U.S. EPA 1988) are suggested for use. Care is required in applying the reported controlled emission factors in accordance with the proper emission control device. Otherwise, a typical removal efficiency for a given control device would need to be applied to published uncontrolled emission factors such as efficiencies that have been reported for common controls used on municipal incinerators (U.S. EPA 1989). It should be noted that an error is evident in the reported controlled particulate emission factor in AP-42 for RDF incinerators (i.e., presumably 0.4 kg particulate/tonne waste, rather than 0.04 kg/tonne). For pit incinerators or other small single-chambered facilities, emission factors reported for industrial/commercial refuse combustors are suggested unless test data are available for individual facilities. All emission factors for MSW incinerators are normally reported as kg/tonne of waste as fired (i.e., such refuse typically contains ~35% moisture.

Furthermore, it should be emphasized that incinerator emissions data can be expected to vary considerably for some pollutants such as particulate matter, carbon monoxide and hydrocarbons. On the other hand, reported emissions data often indicate only small variations of $SO_2$ and $NO_x$. As noted (EPS 1988), some variations are attributable to incinerator operating conditions, such as:

- alterations to the split of primary to secondary air,

- changes in burning bed depths in grate zones and primary air distributions to the grates,
- slag build-up on refractory walls,
- changes in refuse feed (e.g., refuse slugs)

### e) Activity Level

Base quantity and/or operating information for individual municipal incinerators should be obtained from provincial or municipal government agencies or owner/operators of MSW facilities. The type of information recommended to be requested for each facility includes:

- the annual amount of municipal refuse incinerated on an "as-fired' basis or the moisture content if provided on a dry basis,
- typical incinerator operating schedules an facility characteristics (e.g., type of incinerator, number of units operating, typical waste feed rates, normal operating schedule, specialized feed processing, use of heat recovery boilers or other factors that characterize the facility and emissions),
- the type and efficiency of emission control devises used,
- results and documentation of emission testing that has been conducted.

The facility-specific emissions can then be compiled in accordance with amounts of refuse incinerated and test data or applicable emission factors for the class of incinerator.

### f) Alternative Emission Estimation Procedures

The quantities of refuse incinerated have been reported in previous Environment Canada inventories and capacities of individual incinerators have also been reported (Mechler 1984). This information, in conjunction with reported emission factors by type of facility, could be used to estimate the emissions. However, it should be noted that new emission control devices have been recently installed at specific incinerators in Canada and such information should be acquired, in order to apply appropriate emission factors. Where base quantity data are not available for a given facility (e.g., lack of records for small facilities), a procedure to approximate amounts of refuse incinerated, based on typical volumes of combustion gases produced from a given mass of refuse along with permitted hours of operation, has been reported (Edwards and Cotton 1988).

### g) Temporal Variability

Incinerator operating information, acquired through provincial/municipal government or facility-specific contacts, should be used to derive seasonal, daily and hourly emission temporal factors. General operating conditions for various incinerators are also available in specific reports and publications (EPS 1985, EPS 1988, Ozvacic et al 1985, Hay et al 1986, Klicius et al 1987, Thorndyke 1988, Mechler 1984).

### h) Geographical Variability

Locations of large municipal incinerators are known whereby emissions can readily be geographically apportioned. Contact with provincial government environmental ministries should be made in order to define locations of small unit or pit incinerators.

### i) Point Source Establishments

The following municipal solid waste incinerators are currently operating in Canada on the basis of information contained in Environment Canada point source listings and other information. Stack parameter data are also available in Environment Canada Inventory Management Division files.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| PEI | | Parkdale EFW | Parkdale, Charlottetown |
| Quebec | 240065 | Incinerateur CUQ | Quebec City |
| | 240061 | Incinerateur Des Carrieres | Montreal |
| Ontario | | SWARU | Hamilton |
| British Columbia | ? | Vancouver | Burnaby/Vancouver |

## References - Section C.49.1

Alter, H., 1977. "Man is not the Only Polluter". Environmental Science and Technology 11(5):442-448.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Reported prepared for Environment Canada by B.H. Levelton and Associates.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10, Environmental Protection Programs Directorate.

Environment Canada (EPS), 1985. "The National Incinerator Testing and Evaluation Program: Two-Stage Combustion (Prince Edward Island)". Environmental Protection Service Report EPS 3/UP/1, September.

Environment Canada (EPS), 1988. "National Incinerator Testing and Evaluation Program: Environmental Characterization of Mass Burning Incinerator Technology at Quebec City". Environmental Protection Service Report EPS 3/UP/5, June.

Hay, D.J., Finkelstein, A. and Klicius, R., 1986. "The National Incinerator Testing and Evaluation Program Two-Stage Incinerator Combustion Tests". Chemosphere 15(9-12): 1201-1212.

Kilcius, R., Finkelstein, A. and Hay, D.J., 1987. "The National Incinerator Testing and Evaluation Program (NITEP) Mass Burning Technology Assessment". Paper 87-94.5 presented at the 80th Annual Air Pollution Control Association Meeting, New York, N.Y., June.

Mechler, W.A., 1984. "Thermal Destruction of Refuse", Chairman, Lower Mainland Refuse Project Working Committee, Greater Vancouver Sewerage and Drainage District. Referenced in Edwards and Cotton, 1988. "VOC Emissions Method Manual". Report prepared for Environment Canada by B.H. Levelton and Associates.

Ozvacic, V., Wong, G., Tosine, H., Clement, R.E. and Osborne, J., 1985. "Emissions of Chlorinated Organics from Two Municipal Incinerators in Ontario". Journal of the Air Pollution Control Association 35(8):849-855.

Thorndyke, S.J., 1988. "Stack Emission Testing at SWARU for the Regional Municipality of Hamilton-Wentworth", ORTECH International Report P-5675/OG, October.

U.S. Environmental Protection Agency (U.S EPA), 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory". Report prepared by Radian Corp. NTIS PB 87-198735.

## References - Section C.49.1 (Contd.)

U.S. Environmental Protection Agency (U.S. EPA), 1988. "Compilation of Air Pollutant Emission Factors - AP-42, Supplement B", September.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Locating and Estimating Air Toxics Emissions from Municipal Waste Combustors". Report EPA-450/2-89-006, prepared by Radian Corp.

## C.49.2 SEWAGE SLUDGE INCINERATION (SIC 49991)

### a) General Description

Sewage sludge, from municipal wastewater treatment plants, is incinerated in a few Canadian municipalities as a means of waste disposal. Both multiple hearth and fluidized bed sludge incinerators are used in which the sludge is dewatered (15 to 30% solids), preheated to the ignition point and burned in the combustion chamber. All of the common air pollutants are emitted during sewage sludge incineration. Auxiliary fuel may be required to support and maintain combustion due to high moisture content of the sludge.

### b) Process Description

Multiple Hearth/Fluidized Bed Incinerators SCC 5-01-005-06):
The multiple hearth incinerator is a counter-current vertical combustor within a cylindrical furnace shell and consists of three general hearth zones: sludge drying by the hot combustion gases upon entry, sludge burning in the central combustion zone, and the cooling zone whereby hot ash warms the combustion air that enters the furnace (Science Applications 1987). Flue gases, that exit the top of the furnace are directed to a scrubber (i.e., venturi or impingement tray scrubbers are common) and ash discharges from the bottom of the furnace. Fluidized bed incinerators are usually single chamber vertical furnaces containing a sandbed which results in mixing (or fluidizing) sand with sludge by combustion air that enters the furnace bottom. Temperatures of such reactors often remain rather uniform. The less dense sludge ash is carried out of the furnace with flue gases to a venturi scrubber and usually a secondary wet scrubber. In addition to particulate, $SO_2$ and $NO_x$ emissions, incomplete combustion of sludge in these incinerators can result in intermediate product emissions such as volatile organic compounds and carbon monoxide - all of which require efficient emission control.

### c) Inventory Approach

Because of the few numbers of sewage sludge incinerators in Canada and the potential for significant emissions, point source methods should be used in determining emissions. In several instances, source emission measurements have been conducted which should be used to compile facility-specific emissions. Emission factors are also available to check or supplement emissions data where necessary.

### d) Preferred Emission Estimation Procedure

Information sources that can be used to check or calculate emissions for each of the pollutants include:

- specific uncontrolled emission factors developed and reported by Environment Canada based on source measurements (Environment Canada 1983),
- other unpublished Environment Canada reports (Edwards and Cotton 1988),
- uncontrolled and controlled emission factors in AP-42 (U.S. EPA 1988),
- uncontrolled emission factors developed for the NAPAP inventory (U.S. EPA 1987).

As done in previous inventories, it is recommended to acquire operating and emissions data directly from provincial, regional or operator contact. Results from emission test measurements should be used that might update existing data for some pollutants and applied in preference to reported emission factors, as long as data can be verified or adequately checked from process information. In instances where plant-specific emissions data are unavailable (e.g., VOC emissions), the use of emission factors will be required. Where necessary, it is recommended to use AP-42 (U.S. EPA 1988) emission factors, rather than other reported factors, since information related to control device reductions, as well as uncontrolled emissions, is presented for both types of incinerator configuration. At facilities where different emission control devices are used from those reported, the facility-specific control device efficiency should be applied to the reported uncontrolled emission factors. All of the emission factors are reported in units of kg pollutant per tonne of dry sludge. Hence, the extent of sludge dryness should be accounted for when comparing or checking source test data with emission factors. In addition, the reported HC emission factors are available for both methane and non-methane hydrocarbons. Emissions from auxiliary fuel combustion should be included on the basis of applying emission factors (U.S. EPA 1985) in accordance with the type of fuel burned. Account should also be made of pollutant removal efficiencies by the control devices used. The amount of fuel consumed should then be deducted from fuel totals of the industrial fuel combustion sector (see Section B.56).

### e) Activity Level

Operating information pertaining to sewage sludge incinerators should be acquired from Federal or Provincial environmental agencies or directly from the municipal wastewater treatment facility operators. It is recommended to request data such as:

- the amount of sludge incinerated within the year in terms of wet or dry feeds and typical sludge water contents,
- typical incinerator operating schedules and facility characteristics (e.g., type of incinerator, auxiliary fuels consumed),
- the type and efficiency of emission control devices used,
- results and supporting documentation of emission testing that has been conducted at representative operating conditions.

In compiling emissions, facility-specific test data or applicable emission factors should be used in conjunction with amounts of sludge incinerated.

### f) Alternative Emission Estimation Procedures

Quantities of sludge incinerated have been reported in previous Environment Canada inventories and can be updated or assumed to be similar, provided that operating conditions are similar for the given base years. Reported emission factors (U.S. EPA 1988) can then be applied to estimate emissions. In addition, a sulphur balance could be used to estimate $SO_2$ emissions on the basis of the sludge, ash and control device effluent sulphur contents. Similarly, a carbon balance has been suggested by Edwards and Cotton (1988) as an alternative means to estimate VOC emissions by equating the carbon content of the sludge with the carbon and $CO_2$ concentrations of stack gases.

### g) Temporal Variability

Incinerator operating information (e.g., through facility contact) should be used to derive seasonal, daily and hourly emission temporal factors.

### h) Geographical Variability

Sewage sludge incinerator locations are known by compiling emissions on a point source basis such that emissions can be readily geographically apportioned.

### i) Point Source Establishments

The following sewage sludge incinerators are currently operating in Canada on the basis of information in Environment Canada point source listings and other information. Stack parameter data are contained in Environment Canada Inventory Management Division files.

| Province | Plant ID Code | Plant Name | Location |
|---|---|---|---|
| Ontario | 351114 | Woodward Ave. | Hamilton |
| | | Ashbridges Bay | Toronto |
| | | Highland Creek | Toronto |
| | | Duffin Creek | Pickering |
| | | Lakeview | Mississauga |
| | | Victoria Hospital | London |

## References - Section C.49.2

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Report prepared for Environment Canada by B.H. Levelton and Associates.

Environment Canada, Air Pollution Control Directorate, Pollution Data Analysis Division (unpublished information).

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10, Environmental Protection Programs Directorate.

Science Applications International, 1987. (To be completed)

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air
Pollutant Emission Factors - AP-42". 4th Edition.

U.S. Environmental Protection Agency (U.S. EPA), 1987a. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emission Inventory". Report prepared by Radian Corp. NTIS PB 87-198735.

U.S. Environmental Protection Agency (U.S. EPA), 1988. "Compilation of Air Pollutant Emission Factors - AP-42. Supplement B". September.

## C.49.3 INDUSTRIAL/COMMERCIAL WASTE INCINERATION (SIC49992,49993)

### a) General Description

Industrial and commercial solid waste incinerators are typically small-scale units of single or multi-chamber design for disposal of numerous types of refuse. Capacities are reported to vary widely, with feed rates normally ranging between 25 and 1,800 kg/h refuse and an average capacity of approximately 100 kg/h (Energy and Environmental Analysis 1978, Edwards and Cotton 1988, U.S. EPA 1990). Modular units of this nature may be used in various industries, commercial buildings, hotels, institutions and hospitals. They are commonly batch fed, operated intermittently, require auxiliary fuels and are usually operated without emission control devices (Environment Canada 1976, MOE 1986, U.S. EPA 1980). Some of the smaller incinerators (e.g., single chamber) may be characterized by somewhat inefficient combustion with a tendency to emit products of incomplete combustion. Larger facilities may be controlled with afterburners or scrubbers. On a collective basis, such incinerators contribute a relatively small fraction to the national total of common pollutant emissions.

### b) Process Description

The following types of incinerators may be used at industrial, commercial or institutional facilities:

Multiple Chamber Incinerators (SCC 5-02-001-01, 5-03-001-01 and 31300)
Single Chamber (SCC 5-02-001-02, 5-03-001-02)
Controlled Air (SCC 5-02-001-03, 5-03-001-03 and 31500)
Consumat (SCC 5-02-005-91)
Special Purpose (Pathological Waste) (SCC 5-02-005-05)
Industrial (Hazardous Waste) (SCC 5-03-005-01)
Industrial (Sludge) (SCC 5-03-005-06)

Multiple chamber units may be refractory-lined or water-walled furnaces in which refuse is burned on a grate and combustion air is added to primary and secondary chambers, in order to promote more complete oxidation.

Similarly, the common dual-chamber controlled air modular incinerators operate under starved air conditions in the primary chamber with introduction of excess air in the secondary mixing chambers. Small single-chamber units may exhaust the combustion products directly to the stack, but may often be equipped with auxiliary, gas-fired after burners to aid combustion. Similarly, pathological waste incinerators, in which the high-moisture waste is burned on a hearth within the combustion chamber, are normally equipped with combustion controls and afterburners (U.S. EPA 1990). Because of the high plastics content of hospital wastes, potential emissions from older, non-controlled hospital incinerators are of specific concern (Doyle et al 1985, Powell 1987, Brunner and Brown 1988, Chang and Hickman 1989). Industrial wastes, that may comprise numerous types of solid or liquid materials, are combusted in incinerators such as: dual or single chamber units, controlled air packaged units, rotary kilns, metal reclamation furnaces, or co-fired waterwall boilers that may or may not use emission control devices (Accurex 1986, Oppelt 1987, U.S. EPA 1990).

For industrial and commercial incinerators, factors such as the combustor design, waste composition, the operating conditions and control device efficiencies will have pronounced effects on emissions. Accordingly, emission rates might be expected to vary widely between facilities. For example, emissions of uncombusted particulate matter, hydrocarbons and CO can be expected after initial or intermittent charging and during altered combustion conditions. Emissions of $SO_2$ will depend primarily on the sulphur content of the waste and $NO_x$ emissions will normally increase at elevated combustion temperature conditions, or vary with the amount of excess air used (U.S. EPA 1990).

### c) Inventory Approach

Because of the significant number and geographical dispersal of small-sized industrial and commercial incinerators that are presumed to operate in Canada, it is necessary to use area source methods to estimate emissions. Similarly, apart from some larger industrial facilities, source test measurements have not been conducted on the smaller units.

Hence, it is recommended to use published emission factors or facility-specific emission data, where available, to account for these sources.

## d) Preferred Emission Estimation Procedure

Information sources, containing published emission factors, include:

- emission factors reported by Environment Canada for commercial/ industrial multiple chamber and controlled air incinerators (Environment Canada 1983),
- uncontrolled emission factors reported for most types of designs in AP-42 (U.S. EPA 1990),
- uncontrolled emission factors by facility type used in the NAPAP inventory that include additional incinerator categories (U.S. EPA 1987).

Specific differences exist for some of the published emission factors. Where uncertain, it is recommended to use NAPAP factors for hydrocarbon and other pollutant emissions related to specific designs such as controlled air incinerators and AP-42 factors for other pollutants associated with other common facilities. For multiple chamber incinerators, the factors derived by Environment Canada, based on a study of packaged incinerators (McColgan 1977), are lower than those reported in the U.S. for all pollutants except $SO_x$. Thus, further evaluations would be required to select the most appropriate emission factors for some Canadian facilities. All are reported in units of the pollutant emission rate per mass of refuse incinerated and pollutant removal efficiencies by control devices should be applied where specific data are available. For some of the larger industrial facilities, it is suggested to use available source test data, rather than published emission factors.

## e) Activity Level

In most provinces, data are not available regarding the quantity of refuse incinerated by industrial and commercial facilities. In previous

Environment Canada inventories, these base quantity data limitations have necessitated the use of a ratio developed by the U.S. EPA of 9 tonnes of industrial/commercial waste incineration corresponding to 16.6 tonnes of municipal wastes incinerated (Environment Canada 1990). Similarly, it has been assumed that 75% of the waste is burned in multiple chamber incinerators, and the balance in controlled air type incinerators. Amounts of municipal waste incinerated in each province are compiled by provincial authorities. Until more accurate industrial/ commercial waste volume data become available, it is suggested to continue using this approach to estimate emissions from such incinerators. However, it is recommended to acquire incinerated waste data for the larger industrial facilities and hospital incinerators directly from the operators, in order to compile more reliable inventories for these emission sources. Examples of pertinent information for request include:

- the amount and general types of wastes incinerated annually in tonnes, including the liquid content, typical density of the liquid fraction and other known waste characteristics (e.g., sulphur and organic content),
- the typical incinerator operating schedule and amounts of auxiliary fuels consumed,
- where available, emission test data and supporting documentation at representative operating conditions.

### f) Alternative Emission Estimation Procedures

Few alternative emission estimation procedures exist for this sector and, unless additional data acquisitions prove otherwise, a relatively minor national emission impact by such incinerators has been estimated for the common air pollutants.

### g) Temporal Variability

Facility-specific operating data should be used for the larger incinerators, while typical operating characteristics of smaller and intermediate-sized incinerators have been reported with which to temporally allocate emissions (U.S. EPA 1990).

### h) Geographical Variability

The locations of several larger industrial incinerators, as well as specific commercial/institutional and hospital incinerators, are known such that emissions data from these can be readily geographically apportioned. Data from smaller facilities may be apportioned by industrial labour force or population statistics compiled by Statistics Canada.

### i) Point Source Establishments

Lists of several industrial/commercial incinerators are available in provincial government agency records; however, most incinerators within this sector are treated as area sources.

## References - Section C.49.3

Accurex Corporation, 1986. "Dioxin Emissions from Industrial Boilers Burning Hazardous Materials". Report prepared for U.S. Environmental Protection Agency, NTIS PB86-150620.

Brunner, C.R. and Brown, C.H., 1988. "Hospital Waste Disposal by Incineration", Journal of the Air Pollution Control Association 36(10):1297-1309.

Chang, D.P.Y. and Hickman, D., 1989. "Biomedical Waste Incineration". Note to the Editor, Journal of Air Pollution Control Association 39(4):416.

Doyle, B.W., Drum, D.A. and Lauber, J.D., 1985. "The Smouldering Question of Hospital Wastes". Pollution Engineering 17(7):35-39.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions/Methods Manual". Report prepared by B.H. Levelton and Associates for Environment Canada

Energy and Environmental Analysis, 1978. "Preliminary Assessment of the Sources, Control and Population Exposure to Airborne Polycyclic Organic Matter (POM) as Indicated by Benzo(a)Pyrene (BaP)". Prepared for U.S. Environmental Protection Agency, May.

Environment Canada, 1976. "Advances in Small-Scale Refuse Incinerators. Seminar Proceedings". Solid Waste Management Branch Report EPS-3-EC-76-10.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Environmental Protection Programs Directorate Report EPS-3-EP-83-10.

Environment Canada, 1990. "Canadian Emissions Inventory of Common Air Contaminants (1985)". Environmental Protection Service Report EPS 5/AP/3, March.

McColgan, I.J., 1977. "Air Emissions and Control Technology: Packaged Incinerators". Report prepared by Environment Canada EPS 3-AP-77-3, October.

Ontario Ministry of the Environment (MOE), 1986. "Incinerator Design and Operating Criteria - Volume II - Biomedical Waste Incinerators", October.

Oppelt, E.T., 1987. "Incineration of Hazardous Waste. A Critical Review". Journal of the Air Pollution Control Association 37(5):558-585.

Powell, F.C., 1987. "Air Pollution Emissions from the Incineration of Hospital Wastes, the Alberta Experience". Hazardous Waste Management 37(7):836-839.

U.S. Environmental Protection Agency (U.S. EPA), 1990. "Compilation of Air Pollutant Emission Factors. Volume 1. Stationary Point and Area Sources. Supplement C. 4th Edition. Office of Air Quality Planning and Standards, September.

U.S. Environmental Protection Agency, 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP Emission Inventory". Report prepared by Radian Corporation NTIS PB87-198735.

## D.45.1 ON-ROAD MOTOR VEHICLES

### a) General Description

This sector includes the following on-road vehicles:

| SIC | Source Identification | SCC |
|---|---|---|
| 45600 | Light-Duty Gasoline Trucks (LDGT) | 21100 |
| 45601 | Heavy-Duty Gasoline Trucks (HDGT) | 21200 |
| 45602 | Diesel Vehicles - Light Duty Vehicles (LDDV) | 21300 |
| | - Light Duty Trucks (LDDT) | ?? |
| | - Heavy Duty Trucks (HDDT) | 21400 |
| 45890 | Gasoline Powered Automobiles (LDGV) | 21000 |
| 45891 | Gasoline Powered Motorcycles (MC) | 21150 |

The SIC 45602 also includes off-road use of diesel fuel in vehicles which is discussed in Section D.45.3. In some instances, light duty gasoline trucks may be further broken down into LDGT1 and LDGT2, depending on the availability of detailed base quantity information. This system of vehicle classification was developed by the U.S. EPA for use in calculating emission using the U.S. EPA Mobile Models (U.S. EPA 1985).

With the exception of motorcycles, these collective vehicle classes represent a major contribution to $NO_x$, HC and CO emissions. Vehicular exhaust also contributes to particulate matter and $SO_2$ emissions.

### b) Sector Description

The vehicle classes are generally defined as follows (U.S. EPA 1985):

LDGV - light duty gasoline powered vehicles; any gasoline fueled motor vehicle designated primarily for transportation of persons and having a seating capacity of 12 persons or fewer.

LDGT1 - light duty gasoline powered trucks 1; any gasoline fueled motor vehicle designated primarily for transportation of property and rated at 2722 kg (6000 lb) GVW (Gross Vehicle Weight) or less.

LDGT2 - light duty gasoline powered trucks 2; any gasoline fueled motor vehicle designated primarily for transportation of property and rated between 2722 kg (6000 lb) and 3856 kg (8500 lb) GVW inclusive.

HDGV - heavy duty gasoline powered vehicles; any gasoline fueled motor vehicle designated primarily for the transportation of property and rated at more than 3856 kg (8500 lb) GVW, or designated primarily for transportation of persons and having a capacity of 12 persons.

LDDV - light duty diesel powered vehicles; any diesel fueled motor vehicle designated primarily for transportation of persons and having a capacity of 12 persons or fewer.

LDDT - light duty diesel powered trucks; any diesel fueled motor vehicle designated primarily for transportation of property and rated at 3856 kg (8500 lb) or less.

HDDT - heavy duty diesel powered vehicles - any diesel fueled motor vehicle designated primarily for transportation of property and rated at more than 3856 kg (8500 lb) GVW, or designated for transportation of persons and having a capacity of more than 12 persons.

MC - motorcycles; any motor vehicle designed to travel with not more than three wheels in contact with the ground and weighing less than 680 kg (1500 lb).

## c) Inventory Approach

These vehicle classes are classified as area sources of particulate, $SO_2$, $NO_x$, HC and CO. For each vehicle class, the emissions are determined by multiplying the number of vehicle miles travelled per year by an emission factor in grams per mile for each pollutant.

## d) Preferred Emission Estimation Procedure

The emission factors in grams per mile for $NO_x$, HC and CO for each vehicle class are calculated using the MOBILE4 computer modelling program developed by EPA (U.S. EPA 1989). This model has been modified to reflect Canadian conditions. A brief description of MOBILE4 is presented here, followed by information on the Canadian version developed by Environment Canada. Mobile 4 can be acquired for $200.00 (U.S.) through the (U.S.) National Technical Information Service (NTIS).

The test data used to develop the emission factor program include measurement results from thousands of tests on tailpipe and evaporative emissions under a variety of operational and environmental conditions for the various vehicle classes. Most of this testing was done by the U.S. EPA, but data from all sources were used including test data from Environment Canada. U.S. EPA's emission factor data base does not contain adequate data to model emission factors for vehicles using alternative fuels or fuel blends (such as oxygenated fuels). However, procedures have been developed for modelling emission factors for these alternatively fuelled vehicles, which are detailed in the report "Guidance on Estimating Motor Vehicle Emission Reductions From the Use of Alternative Fuels and Fuel Blends" (U.S. EPA 1988).

MOBILE4 provides estimates of emission factors for HC, $NO_x$ and CO for each of the eight vehicle types in two regions of the country: high altitude and low altitude regions. Only the low altitude emissions are applicable to Canadian emissions.

For each vehicle class, MOBILE4 estimates an average HC, $NO_x$ and CO emission factor for each calendar year from 1960 to 2020 inclusive. The 20 most recent model years are considered to be in operation in a given calendar year. Thus, in order to inventory LDGV in 1988 for example, MOBILE4 will model the emission rate in 1988 for each model year from 1969 to 1988. This is calculated by multiplying a deterioration rate in grams per 10,000 miles by the average mileage in 1988 of the cars for a particular model year and adding the product to a constant base (or year 0) emission rate for that model year. Table D.45.1-1 lists the default Jan 1 Mileage Accumulation Rate and Total Mileage Accumulation by model year index for each vehicle class, which is based on U.S. data.

In addition to this deterioration calculation, MOBILE4 incorporates subroutines to calculate the effect of control programs, operating modes, temperature, speed, tampering rates and several other factors which affect tailpipe and/or evaporative HC losses (e.g. ASTM volatility class, base RVP, minimum and maximum ambient temperatures).

Once the calendar year (1988 in our example) emission rate is calculated for each model year, fractional fleet registration mix data are used to indicate the extent to which each model year contributes to the yearly fleet registration mix. Default U.S. registration mix values for light duty gasoline powered vehicles are shown in Table D.45.1-1 as an example.

Table D.45.1-2 shows the 1988 LDGV example of how the fleet mix and mileage accrual rates for each model year are combined to obtain travel fractions for each model year. These travel fractions allow MOBILE4 to calculate a single overall emission rate of each pollutant for each vehicle class by indicating the fraction of the total miles travelled by each vehicle class contributed by each model year.

MOBILE4 was changed to better reflect the Canadian fleet emissions only where there were significant differences between the U.S. and Canadian vehicles and where sufficient information was available to justify the numbers used. Three major changes were made to MOBILE4. The base emission rate and deterioration rate, the fleet technology penetration (used to calculate tampering effects) and evaporative emission rates for light-duty vehicles were changed for the 1980 to 1987 model years. The modified program is referred to as MOBILE4C.

In order to better model the Canadian fleet it was decided to develop emission factors for each province. MOBILE4C uses a maximum and minimum temperature to calculate emission factors. The year was divided into 4 periods that correspond to the periods used to limit gasoline Reed Vapour Pressure (RVP) in the Canadian General Standards Board (CGSB) specification or in provincial regulations. The average maximum and minimum temperature for each period was calculated for the largest city in each province using monthly average maximum and minimum temperatures. This average is based on twenty years of data from 1951 to 1980 (Environment Canada 1982). Provincial registration information was used to develop a unique light-duty vehicle age profile for each province (Desrosiers 1988, Statistics Canada 1986a). A city and highway emission factor was calculated for each of these periods and combined (55% urban/45% highway) to calculate a composite fleet average emission factor. Canadian-specific vehicle miles travelled by each vehicle type have also been input. Table D.45.1-3 summarizes the yearly average distance travelled by vehicle type. Table D.45.1-4 summarizes province-specific $NO_X$ and HC emission factors, in grams/mile, for the 1985 calendar year, as calculated using MOBILE4C. (CCME 1989). Environment Canada intends to produce similar emission factors for CO in the near future.

The Transportation Systems Division (TSD) of Environment Canada is the group responsible for the development of MOBILE4C. TSD is prepared to do custom runs to ensure consistency in model runs and to ensure proper interpretation of input and output variables. Where numerous model runs are required, such as for micro-inventories and researching the impact of specific variables, the end user should plan to acquire a copy of the model and communicate with TSD for specific instructions.

The emissions estimates from MOBILE4 (and MOBILE4C) are sensitive to many variables. The effect of these variables can be different for different pollutants. MOBILE4 has been designed to accommodate city-specific inputs. EPA is aware of these differences and in many cases requires that information be supplied for variables known to have a substantial effect on the emissions estimates. All emissions estimates are uniformly sensitive to estimates of travel and temperature. HC and CO estimates are also sensitive to estimates of speed. The effects of the other variables are dependent on either the pollutant or possibly the distribution selected to estimate the impact. A detailed list of input requirements is provided in U.S. EPA 1989a and a discussion of their effect on emission estimates is discussed in U.S. EPA 1989b.

Composite emission factor for particulate and $SO_2$ emissions are also presented in Table D.45.1-4. The $SO_2$ emission factor is dependent on the sulphur content of the fuel used by each vehicle class. Province-specific gasoline and diesel fuel sulphur content data are supplied in Table D.45.1-7. These factors were supplied by Environment Canada (1990). Environment Canada can provide year-specific sulphur content information.

The following references are recommended for further information on the development of year, fleet and vehicle class specific HC,$NO_x$ and CO emission factors:

U.S. EPA 1985
U.S. EPA 1989 (a and b)
U.S. EPA 1990 (in preparation)

## e) Activity Level

The following is based on Edwards and Cotton (1988), with additions and updates based on Environment Canada (1990 and undated). The reader is also referred to U.S. EPA (1985, 1989 and 1990 (in production)) for further information regarding calculation procedures.

The base quantity for calculating emissions is the distance travelled by the vehicle population in each category. This calculation takes into account the mix of vehicles in the population and their respective distances travelled annually to arrive at the total number of kilometres or miles travelled by all vehicles in each category. The mix of vehicles in each category is also taken into account when determining the emission factor, since the emission characteristics vary with accumulated mileage and year of manufacture.

The simplest way of determining the vehicle kilometres travelled for each vehicle category is to take the product of the average kilometres travelled per vehicle per year and the total number of active vehicles which is the approach used by Environment Canada.

The U.S. EPA has developed a fairly rigorous method for determining the appropriate data for distance travelled by fleets of vehicles included in the various vehicle categories. The method for arriving at distance travelled is documented in Appendix D, Volume 2 of AP-42 (EPA 1985). Appendix H of this same reference provides a complete set of example calculations of distance travelled on average by the vehicle fleet, and as a fraction of the total for each vehicle age in the fleet, for each vehicle category. The procedures followed in arriving at the detailed tabulations for vehicle classes are clearly explained. The calculations for vehicle miles travelled by a vehicle class and the fraction of the total miles travelled by all vehicle classes are calculated by MOBILE4, as discussed in Section d. The user of MOBILE4 has the option of inputting site specific data for these calculations. To proceed with such calculations, the user may input statistics on:

- vehicle count by model year for each vehicle category;
- annual mileage accrual rate by model year for each vehicle category;
- fraction of sales by model year that are gas/diesel fuelled for each vehicle category.

Where this level of data gathering cannot be accomplished, the default statistics for 1981 in the United States can be used. These will differ from Canadian conditions.

Table D.45.1-2, from AP-42 (EPA 1985) illustrates the calculation of the average annual mileage per light duty gasoline powered vehicle (TFNORM) and the fraction of this mileage contributed by each model year (Travel Fractions). Similar tables are given in this reference for each vehicle category. The registration-weighted average annual kilometres travelled per vehicle for each vehicle category, calculated in AP-42 to illustrate the methodology, are summarized in Table D45.1-5. These were calculated assuming a January 1, 1988 registration mix, sales fractions (to correct for fractions of diesel vehicles in traditional gas fueled fleets) and annual mileage accrual rates typical of the United States. These should not necessarily be used for Canada, since vehicle populations, conditions of use and other factors differ; they do however, provide indications of vehicle travel distances. For comparison, average vehicle kilometres travelled as estimated by EAG (1987) for Vancouver and vicinity and for Canada overall (Environment Canada 1990) are also shown in Table D45.1-5. Differences between the values shown serve to illustrate the importance of consolidating vehicle statistics appropriate to the year and area being studied and the uncertainty introduced by utilizing results from other regions.

Vehicle population data by vehicle category can be obtained from Provincial insurance corporations or Ministries of Transportation. Where such data cannot be obtained, a good source is the Inventory Management Division of Environment Canada. This department has purchased vehicle registration data by model year for 25 climatological zones in Canada for 1986. Most of the vehicles under a GVW of 3856 kg are included. Data for heavy duty trucks are not available.

Statistics Canada publishes regular reports on road motor vehicle registrations as illustrated for 1985 in Table D.45.1-6 (Statistics Canada 1986a). It can be seen that this information is grouped into vehicle classes which do not match those used in emission factor derivation.

Table D.45.1-7 shows the data from Table D.45.1-6 after adjustment to match the emission factor classes. The adjustment is based on a number of assumptions:

- all automobiles are grouped together
- the truck vehicle registrations are distributed using the breakdown shown in Figure 45.1-1, which is 1985 specific and was estimated from EMR (1985) and internal Environment Canada reports Table D.45.1-8 shows some of the data used in this derivation for years other than 1985 in order to illustrate the importance of using year-specific data (Environment Canada-n.d.).

Additional details on vehicle registrations can be obtained from Desrosiers, an auto research firm located in Toronto.

Once average annual vehicle miles (or kilometres) and vehicle registrations for each vehicle class have been obtained, the two values are multiplied together to obtain total vehicle miles travelled per vehicle class for the year and area of interest.

A check of the values for vehicle kilometres travelled can be made using statistics for fuel used by the vehicle population in clearly defined regions. Statistics Canada compiles data for amounts of motor fuels sold provincially by year and fuel type (Statistics Canada 1986a and b). The amounts should equal the total kilometres travelled by the vehicle population times the fuel consumed per unit distance travelled. In using this method of checking results, representative average values must be used for the fuel consumed per unit distance travelled by each vehicle in each vehicle category. To assess their accuracy, the calculated values can then be compared directly to the vehicle distance travelled as determined using the methods discussed above.

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Province and vehicle class specific temporal factors are discussed and presented in MEP/ORF (1985).

### h) Geographical Variability

These sources are inventoried on a national or provincial basis. Smaller scale inventories can be accomplished by breaking down provincial emissions using population as a spatial allocation surrogate or by obtaining regional vehicle registration and mix data.

# TABLE D.45.1-1

## Registration Mix and Mileage Accumulation Rates for Low Altitude Light Duty Gasoline Powered Vehicles (January 1)

| Model Year Index** | Jan. 1 Fractional Registration Mix** | Jan. 1 Mileage Accumulation Rate (miles) | Jan. 1 Mileage Accumulation (fleet) |
|---|---|---|---|
| 1 | 0.027 | 12818. | 1602. |
| 2 | 0.101 | 12639. | 9591. |
| 3 | 0.095 | 11933. | 21873. |
| 4 | 0.089 | 11267. | 33470. |
| 5 | 0.083 | 10638. | 44420. |
| 6 | 0.077 | 10045. | 54758. |
| 7 | 0.071 | 9485. | 64520. |
| 8 | 0.065 | 8955. | 73738. |
| 9 | 0.059 | 8455. | 82440. |
| 10 | 0.053 | 7983. | 90657. |
| 11 | 0.047 | 7538. | 98415. |
| 12 | 0.041 | 7117. | 105740. |
| 13 | 0.035 | 6720. | 112657. |
| 14 | 0.029 | 6345. | 119187. |
| 15 | 0.023 | 5991. | 125354. |
| 16 | 0.017 | 5657. | 131176. |
| 17 | 0.011 | 5340. | 136673. |
| 18 | 0.008 | 5043. | 141863. |
| 19 | 0.006 | 4761. | 146763. |
| 20+ | 0.008 | 4495. | 151390. |

* Default information that may be altered by the user with information for the local area, or time of year.

** The indices refer to the most recent model year vehicles in any given calendar year. Index 1 references the newest model year vehicles and index 20+ references the oldest model year vehicles.
Date: May 25, 1985
(U.S. EPA 1985)

# TABLE D.45.1-2

## Example Travel Weighting Fraction Calculation for Low Altitude Light Duty Gasoline Powered Vehicles
## January 1, 1988

| Model Years | (A) LDV Fleet Registration | (B) Sales Fraction | (A*B) | (C=A*B/DAF) LDGV Registration | (D) Annual Mileage Accrual Rate | (C*D) | (C*D/TFNORM) Travel Fractions |
|---|---|---|---|---|---|---|---|
| 1988 | 0.027 | 0.910 | 0.024 | 0.027 | 12818. | 345.4 | 0.036 |
| 1987 | 0.101 | 0.920 | 0.093 | 0.103 | 12639. | 1304.3 | 0.137 |
| 1986 | 0.095 | 0.923 | 0.088 | 0.097 | 11933. | 1162.1 | 0.122 |
| 1985 | 0.089 | 0.934 | 0.083 | 0.092 | 11267. | 1040.2 | 0.109 |
| 1984 | 0.083 | 0.940 | 0.078 | 0.087 | 10638. | 921.8 | 0.097 |
| 1983 | 0.077 | 0.947 | 0.073 | 0.081 | 10045. | 813.5 | 0.085 |
| 1982 | 0.071 | 0.954 | 0.068 | 0.075 | 9485. | 713.5 | 0.075 |
| 1981 | 0.065 | 0.939 | 0.061 | 0.068 | 8955. | 607.0 | 0.064 |
| 1980 | 0.059 | 0.966 | 0.057 | 0.063 | 8455. | 535.2 | 0.056 |
| 1979 | 0.053 | 0.972 | 0.052 | 0.057 | 7983. | 456.7 | 0.048 |
| 1978 | 0.047 | 0.991 | 0.047 | 0.052 | 7538. | 389.9 | 0.041 |
| 1977 | 0.041 | 0.996 | 0.041 | 0.045 | 7117. | 322.8 | 0.034 |
| 1976 | 0.035 | 0.997 | 0.035 | 0.039 | 6720. | 260.4 | 0.027 |
| 1975 | 0.029 | 0.997 | 0.029 | 0.032 | 6345. | 203.7 | 0.021 |
| 1974 | 0.023 | 1.000 | 0.023 | 0.026 | 5991. | 153.0 | 0.016 |
| 1973 | 0.017 | 1.000 | 0.017 | 0.019 | 5657. | 106.8 | 0.011 |
| 1972 | 0.011 | 1.000 | 0.011 | 0.012 | 5340. | 65.2 | 0.007 |
| 1971 | 0.008 | 1.000 | 0.008 | 0.009 | 5043. | 44.8 | 0.005 |
| 1970 | 0.006 | 1.000 | 0.006 | 0.007 | 4761. | 31.7 | 0.003 |
| 1969- | 0.008 | 1.000 | 0.008 | 0.009 | 4495. | 39.9 | 0.004 |
|  |  | DAF: | **0.902** |  | TFNORM: | **9518.0** |  |

where:

A = January 1 registration mix from Table D.45-1
B = Fleet sales fractions (fraction of sales that are gasoline vs. diesel)
D = Sales weighted fleet mileage accumulation rate from Table 45.1-1 adjusted to January 1
D(1) = Annual Miles (1)
D (MY1) = 25* (Annual Miles (MY1)) + .75* (Annual Miles (MY1-1)), MY1=2, ..,20+

NOTE: In general, the travel weighting fractions will change for every calendar year since the sales fraction (column B) changes for almost every model year.

DATE: May 25, 1985
(U.S. EPA 1985)

## TABLE D.45-1-3

## Yearly Average Distance Travelled by Vehicle Type

| Vehicle Type | Vehicle Miles Travelled |
|---|---|
| Automobile | 9,500 |
| Light Duty Gasoline Trucks | 11,000 |
| Light Duty Diesel Trucks | 11,000 |
| Heavy Duty Gasoline Trucks | 12,500 |
| Heavy Duty Diesel Trucks | 51,500 |
| Motorcycles | 1,750 |
| Snowmobiles | 1,750 |

# TABLE D.45.1-4a

## Weighted Average $NO_X$/VOC and Composite Particulate Matter Emission Factors - 1985 (grams/mile) (obtained from MOBILE4C on December 18, 1989)

| Province | | LDGT | HDGT | LDDV | HDDV | Autos | Motorcycles | Snow-Mobiles** |
|---|---|---|---|---|---|---|---|---|
| NFLD (St. John) | VOC | 4.877 | 7.773 | 0.544 | 2.629 | 3.165 | 4.029 | 21.600 |
| PEI (N.S....Halifax) | VOC | 4.829 | 8.066 | 0.544 | 2.629 | 3.239 | 4.066 | 21.600 |
| N.S. (Halifax) | VOC | 4.829 | 8.066 | 0.544 | 2.629 | 3.239 | 4.066 | 21.600 |
| N.B. (St. John) | VOC | 4.942 | 8.003 | 0.544 | 2.629 | 3.364 | 4.018 | 21.600 |
| Quebec (Montreal) | VOC | 5.083 | 8.601 | 0.544 | 2.629 | 3.472 | 4.483 | 21.600 |
| Ontario (Toronto) | VOC | 5.101 | 8.746 | 0.544 | 2.629 | 3.700 | 4.684 | 21.600 |
| Manitoba (Winnipeg) | VOC | 5.576 | 8.708 | 0.544 | 2.629 | 4.549 | 4.455 | 21.600 |
| Saskatchewan (Reg.) | VOC | 5.659 | 8.752 | 0.544 | 2.629 | 4.701 | 4.532 | 21.600 |
| Alberta (Calgary) | VOC | 5.224 | 8.431 | 0.544 | 2.629 | 4.113 | 4.185 | 21.600 |
| BC/Yukon/NWT | VOC | 5.260 | 10.540 | 0.544 | 2.629 | 4.176 | 4.067 | 21.600 |
| * Composite | THC | 7.95 | 14.64 | 0.34 | 3.96 | 5.119 | 8.83 | 21.600 |
| NFLD (St. John) | $NO_X$ | 3.591 | 7.454 | 2.080 | 24.320 | 3.081 | 1.009 | 0.340 |
| PEI (N.S....Halifax) | $NO_X$ | 3.521 | 7.371 | 2.080 | 24.320 | 3.057 | 0.984 | 0.340 |
| N.S. (Halifax) | $NO_X$ | 3.521 | 7.371 | 2.080 | 24.320 | 3.057 | 0.984 | 0.340 |
| N.B. (St. John) | $NO_X$ | 3.571 | 7.437 | 2.080 | 24.320 | 3.134 | 0.999 | 0.340 |
| Quebec (Montreal) | $NO_X$ | 3.539 | 7.388 | 2.080 | 24.320 | 3.075 | 0.964 | 0.340 |
| Ontario (Toronto) | $NO_X$ | 3.530 | 7.353 | 2.080 | 24.320 | 3.179 | 0.964 | 0.340 |
| Manitoba (Winnipeg) | $NO_X$ | 3.662 | 7.545 | 2.080 | 24.320 | 3.508 | 0.974 | 0.340 |
| Saskatchewan (Reg.) | $NO_X$ | 3.682 | 7.571 | 2.080 | 24.320 | 3.568 | 0.984 | 0.340 |
| Alberta (Calgary) | $NO_X$ | 3.627 | 7.493 | 2.080 | 24.320 | 3.450 | 1.009 | 0.340 |
| BC/Yukon/NWT | $NO_X$ | 3.460 | 7.275 | 2.080 | 24.320 | 3.343 | 0.989 | 0.340 |
| * Composite | $NO_X$ | 4.84 | 8.35 | 1.62 | 26.54 | 3.89 | 0.71 | 0.340 |
| * Composite | PART | 0.30 | 0.90 | 0.30 | 1.95 | 0.30 | 0.37 | 0.95 |

* Composite emission factors are for all climate zone and provinces. VOC is 90% of THC for gasoline and 95.6% of THC for diesel.

** For use in inventorying off-road gasoline use. See Section D.45.2.

# TABLE D.45.1-4b

## Weighted Average $SO_x$/CO Emission Factors - 1985
## (grams/mile)
## (obtained from MOBILE 4C on May 30, 1990)

| Province | | LDGT | HDGT | LDDV | HDDV | Autos | Motorcycles | Snowmobiles*** |
|---|---|---|---|---|---|---|---|---|
| NFLD (St. John) | $SO_x$ | 4.187 | 7.542 | 1.372 | 2.472 | 2.320 | 1.984 | 0.614 |
| PEI (N.S....Halifax) | $SO_x$ | 4.302 | 7.749 | 0.650 | 1.171 | 2.384 | 1.422 | 0.631 |
| NS (Halifax) | $SO_x$ | 4.512 | 8.127 | 1.498 | 2.699 | 2.500 | 1.491 | 0.661 |
| NB (St. John) | $SO_x$ | 4.480 | 8.070 | 2.997 | 5.400 | 2.483 | 1.481 | 0.657 |
| Quebec (Montreal) | $SO_x$ | 5.195 | 9.358 | 7.171 | 12.922 | 2.879 | 1.717 | 0.762 |
| Ontario (Toronto) | $SO_x$ | 5.236 | 9.432 | 4.170 | 7.516 | 2.902 | 1.730 | 0.768 |
| Manitoba (Winnipeg) | $SO_x$ | 3.557 | 6.408 | 2.739 | 4.936 | 1.972 | 1.176 | 0.521 |
| Saskatchewan (Regina) | $SO_x$ | 3.932 | 7.083 | 2.778 | 5.007 | 2.179 | 1.300 | 0.576 |
| Alberta (Calgary) | $SO_x$ | 4.749 | 8.554 | 5.382 | 9.698 | 2.632 | 1.569 | 0.696 |
| BC | $SO_x$ | 3.400 | 6.125 | 2.628 | 4.736 | 1.858 | 1.124 | 0.498 |
| Yukon/NWT | $SO_x$ | 0.189 | 0.359 | 11.879 | 21.408 | 0.110 | 0.066 | 0.029 |
| *Composite | $SO_x$** | 4.98 | 8.97 | 4.64 | 8.37 | 2.76 | 1.65 | 0.73 |
| NFLD (St. John) | CO | 44.860 | 100.200 | 0.830 | 10.930 | 30.290 | 18.560 | 33.54 |
| PEI (N.S....Halifax) | CO | 42.870 | 98.630 | 0.830 | 10.930 | 29.900 | 17.880 | 33.54 |
| NS (Halifax) | CO | 42.870 | 98.680 | 0.830 | 10.930 | 29.900 | 17.880 | 33.54 |
| NB (St. John) | CO | 44.580 | 99.930 | 0.830 | 10.930 | 31.610 | 18.280 | 33.54 |
| Quebec (Montreal) | CO | 44.000 | 99.010 | 0.830 | 10.930 | 30.550 | 17.370 | 33.54 |
| Ontario (Toronto) | CO | 43.500 | 98.740 | 0.830 | 10.930 | 32.460 | 17.480 | 33.54 |
| Manitoba (Winnipeg) | CO | 48.950 | 102.000 | 0.830 | 10.930 | 40.800 | 17.690 | 33.54 |
| Saskatchewan (Regina) | CO | 49.630 | 102.500 | 0.830 | 10.930 | 42.280 | 17.940 | 33.54 |
| Alberta (Calgary) | | 46.420 | 101.000 | 0.830 | 31.170 | 38.440 | 18.600 | 33.54 |
| BC/Yukon/NWT | CO | 40.950 | 96.880 | 0.830 | 10.930 | 35.460 | 18.090 | 33.54 |
| *Composite | CO | 54.02 | 151.8 | 0.98 | 11.37 | 40.54 | 25.85 | 33.54 |

* Composite emission factors are for all climate zones and provinces

** Multiply by sulphur content of fuel (see Table D.45.1-7 for province-specific sulphur content of gasoline and diesel fuel)

*** For use in inventorying off-road gasoline use, see Section D.45.2

## TABLE D.45.1-5

## Example Values for Annual Vehicle Kilometers Travelled Per Vehicle for all Vehicle Categories (Environment Canada 1988)

| | United States | Canada | Greater Vancouver |
|---|---|---|---|
| **Basis** | - Jan. 1, 1988 registration mix (estimated from 1985)<br>- Projected fleet sales fractions Environment Canada<br>- other data as per Mobile3 defaults | - 1985 registration mix (actual)<br>- based on Statistics Canada (1986) and model years reported | - 1985 registration mix (actual)<br>- no annual kilometer accrual rates for |
| **Source** | EPA 1985 | Env. Canada 1990 | EAG 1987 |
| **Annual Vehicle Kilometres Travelled by Vehicle Category (km)** | | | |
| Gasoline Vehicles: | | | |
| LDGV | 15,300 | 15,289 | 14,000 |
| LDGT1 | 17,600 | 17,703 | 15,300 |
| LDGT2 | 18,100 | 17,703 | 15,800 |
| HDGV | 20,900 | 20,117 | 19,000 |
| MC | 3,100 | 2,816 | 3,100 |
| Diesel Vehicles: | | | |
| LDDV | 17,500 | 15,289 | 14,000 |
| LDDT | 23,800 | 17,703 | 15,500 |
| HDDV | 73,800 | 82,881 | 49,300 |

## TABLE D.45.1-6

## Road Motor Vehicle Registrations - 1985 - Provinces Only

| Vehicle Type | Canada | Nfld. | P.E.I. | N.S. | N.B. | Que. | Ont. | Man. | Sask. | Alta. | B.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Automobiles | 11,118,071 | 168,416 | 54,533 | 366,172 | 278,106 | 2,483,413 | 4,093,730 | 512,733 | 387,260 | 1,289,040 | 1,468,413 |
| Trucks and tractors | 3,095,243 | 72,175 | 18,823 | 142,279 | 114,265 | 300,570 | 904,111 | 208,036 | 296,785 | 386,201 | 626,743 |
| Buses: | | | | | | | | | | | |
| School | 25,773 | 1,002 | 392 | | | 8,161 | 8,364 | | 3,360 | 4,446 | |
| Other | 27,512 | | 25 | 1,518 | | 4,640 | 16,635 | 163 | 1,100 | 3,154 | |
| Total | 53,285 | 1,002 | 417 | 1,518 | | 12,801 | 24,999 | 163 | 4,460 | 7,600 | |
| Motorcycles | 452,526 | 10,156 | 2,141 | 18,775 | 11,836 | 105,478 | 149,441 | 18,481 | 8,148 | 46,446 | 79,876 |
| Other Road motor Vehicles | 64,103 | 5,801 | 138 | 317 | 11,300 | 46,041 | | 75 | 264 | | |
| Snowmobiles | 455,350 | 59,574 | 40 | 5,905 | | 73,605 | 209,290 | 21,457 | 10,527 | 24,500 | 49,970 |

Source: Statistics Canada 1986a

# TABLE D.45.1-7

## Adjusted Road Motor Vehicle Registrations - 1985 Provinces Only

| Vehicle Type | Canada | Nfld. | P.E.I. | N.S. | N.B. | Que. | Ont. | Man. | Sask. | Alta. | B.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Automobiles | 11,118,071 | 168,416 | 54,533 | 366,172 | 278,106 | 2,483,413 | 4,093,730 | 512,733 | 387,260 | 1,289,040 | 1,468,413 |
| LDGT | 2,244,085 | 52,328 | 13,647 | 103,154 | 82,843 | 217,917 | 655,490 | 150,828 | 215,172 | 280,000 | 454,395 |
| LDDT | 201,588 | 4,701 | 1,226 | 9,266 | 7,442 | 19,576 | 58,883 | 13,549 | 19,329 | 25,153 | 40,819 |
| HDGV | 285,646 | 7,062 | 1,972 | 11,946 | 9,594 | 33,397 | 84,272 | 17,466 | 28,278 | 36,871 | 52,621 |
| HDDV | 216,353 | 4,428 | 1,179 | 10,189 | 7,011 | 22,901 | 71,460 | 12,921 | 19,267 | 26,727 | 38,455 |
| Motorcycles | 452,526 | 10,156 | 2,141 | 18,775 | 11,836 | 105,478 | 149,441 | 18,481 | 8,148 | 46,446 | 79,876 |
| Other Road Motor Vehicles | 64,103 | 5,801 | 138 | 317 | 11,300 | 46,041 |  | 75 | 264 |  |  |
| Snowmobiles | 455,350 | 59,574 | 40 | 5,905 |  | 73,605 | 209,290 | 21,457 | 10,527 | 24,500 | 49,970 |
| % Sulphur in Gasoline |  | 0.032 | 0.032 | 0.032 | 0.032 | 0.0256 | 0.0256 | 0.024 | 0.024 | 0.024 | 0.024 |
| % Sulphur in Diesel |  | 0.252 | 0.252 | 0.252 | 0.252 | 0.255 | 0.255 | 0.137 | 0.137 | 0.137 | 0.137 |

Source: Environment Canada 1990. The % sulphur in gasoline and diesel reported in this reference were based on RTM Engineering Ltd., 1988.

## TABLE D.45.1-8

### Distribution of Trucks by Fuel Type

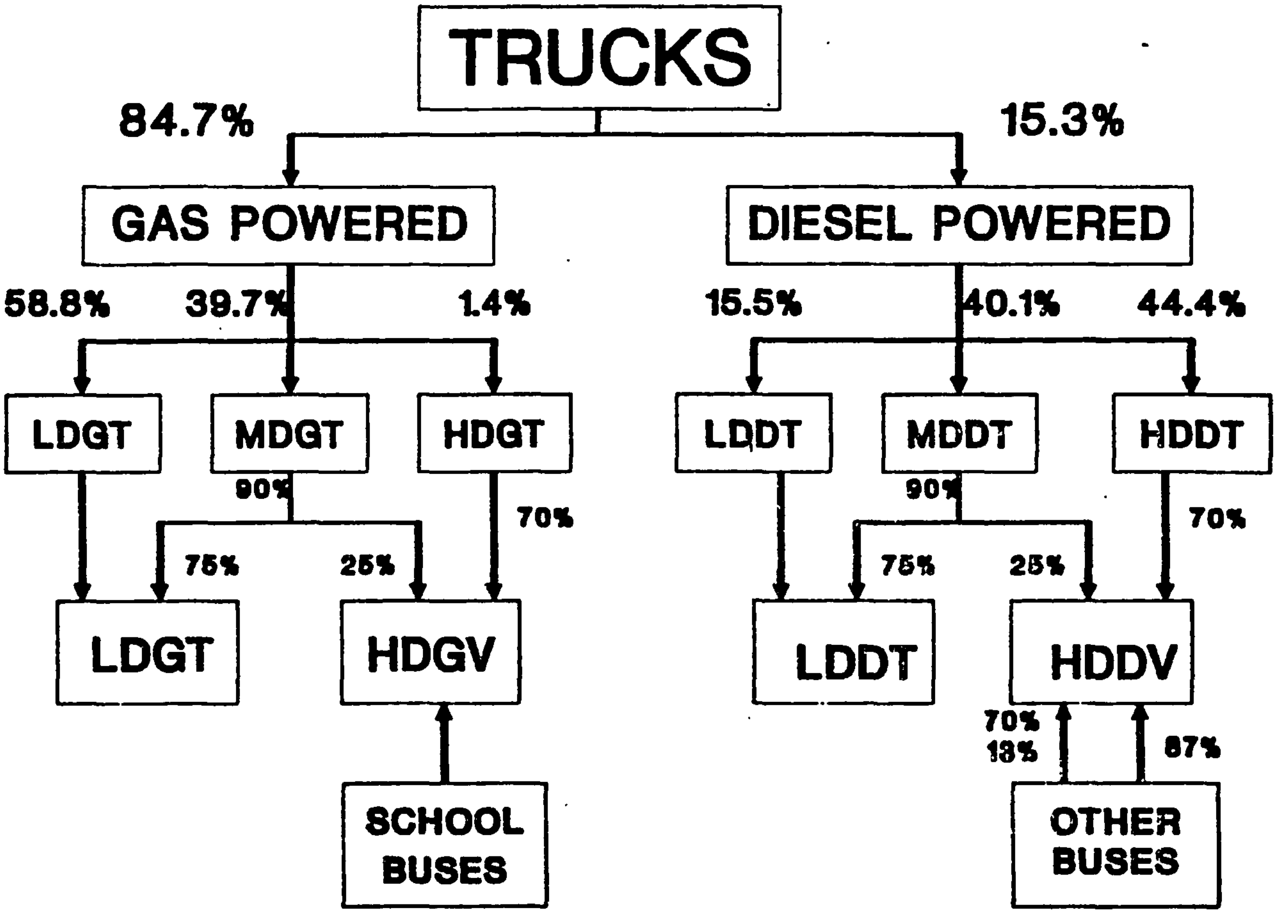
| | % Diesel | % Gasoline |
|---|---|---|
| 1975 | 3.7 | 96.3 |
| 1976 | 4.6 | 95.4 |
| 1977 | 6.1 | 93.9 |
| 1978 | 7.6 | 92.4 |
| 1979 | 9.4 | 90.6 |
| 1980 | 11.6 | 88.4 |
| 1981 | 12.2 | 87.8 |
| 1982 | 13.1 | 86.9 |
| 1983 | 13.9 | 86.1 |
| 1984 | 14.8 | 85.2 |
| 1985 | 15.3 | 87.7 |

### Distribution of Trucks by Weight & Fuel Type (By Percent)

| | | (Gasoline) | | | (Diesel) | |
|---|---|---|---|---|---|---|
| | LDGT | MDGT | HDGT | LDDT | MDDT | HDDT |
| 1975 | 31.8 | 57.1 | 11.2 | 0 | 0 | 100 |
| 1976 | 34.4 | 56.1 | 9.6 | 0 | 0.1 | 99.5 |
| 1977 | 37.2 | 55.4 | 7.5 | 0 | 0.1 | 99.2 |
| 1978 | 39.4 | 54 | 6.6 | 10.3 | 6.6 | 83.2 |
| 1979 | 41.6 | 52.9 | 5.6 | 17.6 | 10.4 | 71.6 |
| 1980 | 43.9 | 51.9 | 4.2 | 22.6 | 12.9 | 64.4 |
| 1981 | 46.7 | 49.3 | 3.9 | 21.1 | 21.2 | 57.7 |
| 1982 | 49.7 | 47 | 3.4 | 19.5 | 27.4 | 53.1 |
| 1983 | 52.7 | 44.5 | 2.8 | 18.1 | 32.4 | 49.8 |
| 1984 | 56.0 | 42.2 | 1.9 | 16.3 | 36.2 | 47.3 |
| 1985 | 58.8 | 39.7 | 1.4 | 15.5 | 40.1 | 44.4 |

Environment Canada n.d.

FIGURE D.45.1-1



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## D.45.2 OFF-ROAD USE OF GASOLINE (SIC 45894)

### a) General Description

Off-road sources include most motorized equipment and vehicles that are not normally operated on public highways to provide transportation service (U.S. EPA 1989). Five main types of equipment are considered in this class: construction, agricultural, forestry, general utility or industrial engines and snowmobiles. Emissions of particulate matter, $SO_2$, $NO_x$, HC and CO are inventoried for this sector.

### b) Sector Description

Snowmobiles are inventoried under SCC 22140.

All other off-road gasoline-fueled sources are included under SCC 22100.

Agricultural equipment includes two main types of sources: tractors and all other motorized equipment. The primary types of equipment, other than tractors, are combines, balers, harvesters and general purpose machines.

A wide variety of equipment is used in the construction industry. There is no standard classification system by which construction equipment is described, although the general function of the equipment and the available horsepower are parameters used in classification. General function categories include bulldozers, power shovels, scrapers, haulers and motor graders (U.S. EPA 1989).

Vehicles used in the forestry industry are similar to those used in the construction sector, excluding scrapers, rollers and graders.

The class of utility equipment includes a wide variety of types and sizes of machinery. Examples of equipment included in this category are forklifts, mobile refrigeration units; auxiliary engines for hydraulic pump service on garbage trucks and other large vehicles; generator and pump service for utilities, airports and maintenance organizations; and equipment for such operations as mining, quarrying, oil field operations and portable well drilling equipment (U.S. EPA 1989).

Smaller utility engines include 2-stroke and 4-stroke, air-cooled, gasoline-fueled engines. These are found on lawnmowers, small electric generators, compressors, pumps, snowthrowers, garden tractors and mini bikes, but excludes motorcycles, outboard motors, chainsaws and snowmobiles (Edwards and Cotton 1988).

### c) Inventory Approach

Snowmobiles are inventoried as an area source, using emission factors and activity levels based on mileage. The methods for snowmobile inventory are described in Section D.42.1. All other off-road use of gasoline is inventoried as an area source using emission factors and activity levels based on fuel use.

### d) Preferred Emission Estimation Procedure

The following references are recommended:

- Environment Canada 1983
- U.S. EPA 1985 (a and b)
- U.S. EPA 1989

Environment Canada (1983) provides a summary of emission factors by vehicle class. In addition, Environment Canada recommends that a straight average of the factors for agricultural, heavy-duty construction and industrial equipment be used. The industrial engine emission factors are for stationary sources (see U.S. EPA 1986b and 1989). A weighted average, based on the relative fuel use of these categories, was not possible as detailed fuel usage estimates were not available. The average emission factors in kg/L$^3$ calculated were:

| | | |
|---|---|---|
| particulates | 0.841 | |
| $SO_2$ | 14.77S | (S = sulphur content) |
| $NO_x$ | 13.56 | |
| HC | 24.10 | |
| CO | 453.00 | |

The average $SO_2$ emission factor of 0.635 kg/$L^3$ calculated from AP-42 (U.S. EPA (1985a) was corrected (as above) to be dependent on study specific gasoline sulphur contents instead of 0.043%.
U.S. EPA (1985a and 1989) provided detailed emission factor data and further insight into what they represent.

## e) Activity Level

The activity level is required in units of $10^3$L used. The quantity of gasoline used can be obtained from Statistics Canada Publication 53-218 "Road Motor Vehicles Fuel Sales" by subtracting net fuel sales from gross fuel sales. Since net sales is on-road sales and gross sales is total sales, the difference between them is off-road use of gasoline. Sometimes adjustments must be made to this data. For example, in a recent inventory conducted by Environment Canada, three province's quantities for 1985 on-road sales of gasoline were unavailable. Alberta's and Saskatchewan's statistics were not published due to a removal of their provincial tax which inhibits the process of computing these values. For these provinces, increments were evaluated from consumption in previous years to establish estimates for 1985. (Edwards and Cotton 1988)

Breaking this information down into equipment categories can be difficult. Some further information is available in Statistics Canada report 57-003 on energy supply and demand.

Statistics Canada report 64-202 gives data on the number of lawnmowers. This can be used to estimate emissions from this off-road source group which makes up a large proportion of the total small utility engines in use. AP-42 states that 89% of all small utility engines in the United States as of 1971 were for lawn and garden applications (Edwards and Cotton 1988).

### f) Alternative Emission Estimation Procedures

If detailed activity level information is available by equipment type, these sources could be inventoried individually using emission factors as presented in AP-42 (U.S. EPA 1985a).

### g) Temporal Variability

U.S. EPA (1989) provides some information on the temporal variability of emissions from these equipment classes.

### h) Geographical Variability

Data is available on a provincial basis for fuel use by these classes. Further geographical apportionment could be done on the basis of labour force statistics available from Environment Canada.

## References - Section D.45.2

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd.

Statistics Canada, "Household Equipment and Facilities". Publication Number 64-202.

Statistics Canada, "Quarterly Report on Energy Supply-Demand". Publication Number 57-003.

Statistics Canada, "Road Motor Vehicles Fuel Sales". Publication Number 53-218.

U.S. Environmental Protection Agency (U.S. EPA), 1985a. "Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources". Fourth Edition. Report No. AP-42. U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

U.S. Environmental Protection Agency (U.S. EPA), 1985b. "Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources". AP-42, Fourth Edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, Revised". EPA-450/4-81-026d (revised). U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

## D.45.3 OFF-ROAD USE OF DIESEL (SIC 45602)

### a) General Description

Internal combustion diesel engines used in the mining, agricultural, construction, manufacturing, forestry, public administration and pipelines sectors of the economy are considered in this category. The emissions from diesel engines used in road, railways and marine vehicles are considered in other sections of this manual. Particulate matter, $NO_x$, $SO_x$, CO and HC are emitted from this sector. Off-highway use of diesel fuel results in significant emissions of $NO_x$.

### b) Sector Description

SCC's and brief equipment descriptions for the sectors included in this group of diesel engines are as follows:

Agricultural Equipment (SCC 22210):
Agricultural equipment comprises farm tractors and other farm machinery such as self-propelled combines, forage harvesters, irrigation pumps and auxiliary engines on pull-type combines and balers.

Construction Equipment (SCC 22220):
The construction industry uses various types of heavy-duty diesel machinery such as track type tractors and loaders, motor graders, wheel tractor scrapers, wheel dozers, wheel loaders and other miscellaneous machines such as hydraulic excavators/crawlers, trenchers, concrete pavers, cranes and bituminous pavers.

Mining Equipment (SCC 22230):
The diesel vehicles used for mining activities comprises wheeled loaders, off-highway trucks, wheeled dozers and scrapers, motor graders and miscellaneous heavy duty equipment as used in the construction industry. Other industrial diesel engines such as power plants, fork lift trucks and pumps are also used.

Manufacturing Equipment (SCC 22240):
A variety of diesel combustion engines are used in the manufacturing industry, including equipment such as fork lift trucks, mobile refrigeration units, generators and pumps.

Forestry Equipment (SCC 22250):
The diesel vehicles used in the forestry sector are similar to the ones used in the construction sector except for scrapers, motor graders and rollers.

Public Administration Equipment (SCC 22260):
The diesel engines used by this sector include industrial engine types (fork lift truck, generators, pumps, etc.) and heavy machinery such as off-highway trucks, motor graders and rollers. Commercial/institutional off-road use of diesel fuel is included in this SCC.

Pipeline Equipment (SCC 22270):
The engines used by this sector are similar to the ones included in the industrial diesel engines group.

## c) Inventory Approach

The diesel engines sectors described in Section b) are inventoried individually as area sources, using sector-specific emission factors and activity levels based on fuel use.

## d) Preferred Emission Estimation Procedure

The U.S. EPA has developed fuel-based emission factors for a variety of off-road vehicles (U.S. EPA 1985a and b). Environment Canada has developed sector-specific average emission factors based on the U.S. EPA data. These are presented in Table D.45.3-1, along with details on the assumptions used in their derivation.

Ingalls (1985) has reviewed some more recent emission factor data. Further insight into emission estimation procedures can be found in U.S. EPA (1989).

### e) Activity Level

Provincial diesel fuel consumptions for the sectors described above can be obtained from Statistics Canada publication 57-003. Use "Total Manufacturing" for manufacturing equipment and the sum of "Public Administration" plus "Other Commercial/Institutional" for public administration equipment.

### f) Alternative Emission Estimation Procedures

Detailed inventories could be conducted using the detailed emission factors in AP-42 (1985 a and b) if fuel-based activity levels are available in the same format.

### g) Temporal Variability

Data is available on a quarterly basis. Temporal factors are presented and discussed in a report by MEP Company and Ontario Research Foundation (1985).

### h) Geographic Variability

Data is available on a provincial basis. Further geographical apportionment could be done on the basis of labour force statistics available from Environment Canada.

## TABLE D.45.3-1

## Average Emission Factors Derived by Environment Canada for Off-Road Diesel Fuel Use (kg/$10^3$ L) (Environment Canada 1990)

| Sector | CO | $NO_x$ (as $NO_2$) (Exhaust) | $SO_x$ (as $SO_2$) | Particulate | HC |
|---|---|---|---|---|---|
| Agricultural[1] | 14.52 | 39.89 | 17.00S[7] | 5.54 | 7.24 |
| Construction[2] | 15.09 | 39.34 | 16.98S | 3.13 | 3.79 |
| Mining[3] | 12.28 | 43.87 | 16.99S | 3.30 | 3.55 |
| Manufacturing[4] and Pipeline | 12.20 | 56.20 | 17.00S | 4.01 | 4.49 |
| Forestry[5] | 16.08 | 40.70 | 16.985 | 3.21 | 4.45 |
| Public[6] Administration | 13.42 | 46.97 | 16.98S | 3.29 | 3.36 |

1. A breakdown of 91% for tractor equipment and of 9% for non-tractor farm equipment was used to estimate average emission factors for this sector (Statistics Canada 1982).
2. Due to the diversity of construction projects and type of machinery, all of the heavy equipment factors available were averaged.
3. Assumed to be 40% industrial equipment and 60% heavy-duty construction equipment (dozer, scraper, motor grader, wheeled loader, off-highway truck and miscellaneous).
4. Factors are for industrial equipment.
5. Average of heavy duty construction equipment less the scrapers, motor graders and rollers.
6. Assumed to be 50% industrial equipment and 50% heavy duty construction equipment (off-highway trucks, motor graders and rollers only).
7. Sulphur content of the fuel (see Table D.45.3-2).

## TABLE D.45.3-2

### Average Sulphur Content for Diesel (1985)*
### (Environment Canada 1990)

| Province | Weight Percent |
|---|---|
| Newfoundland | 0.25166 |
| Prince Edward Island | 0.25166 |
| Nova Scotia | 0.25166 |
| New Brunswick | 0.25166 |
| Quebec | 0.25469 |
| Ontario | 0.25469 |
| Manitoba | 0.13704 |
| Saskatchewan | 0.13704 |
| Alberta | 0.13704 |
| British Columbia | 0.13704 |
| Yukon/N.W.T. | 0.13704 |

* Note that sulphur content is year-specific.

## References - Section D.45.3

Environment Canada, 1990. Internal document.

Ingalls, M.N., 1985. "Recommended Revisions to Gaseous Emission Factors from Several Classes of Off-Highway Mobile Sources". Prepared by the Southwest Research Institute for the U.S. EPA. EPA 460/3-85-004. U.S. Environmental Protection Agency, Ann Arbor, Michigan.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume 1: Report. Volume II: Appendix". Prepared for Environment Canada.

Statistics Canada, n.d. "Quarterly Report on Energy Supply - Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985a. "Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources". Fourth Edition. Report No. AP-42. U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

U.S. Environmental Protection Agency (U.S. EPA), 1985b. "Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources". AP-42, Fourth Edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, Revised". EPA-450/4-81-026d (revised). U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

## D.45.4 RAILROADS (SIC 45310)

### a) General Description

The primary emission source from railroads is locomotives. Although crude oil is used for secondary power generation (primarily heating), the amounts used are considered to be insignificant and this source is not inventoried.

Diesel-electric locomotives are the only potentially significant source of $NO_x$, $SO_2$, CO, HC and particulates. Electric locomotives are powered by electricity generated at stationary power plants and distributed by either a third rail or overhead catenary system. Emissions are produced only at the electrical generation station, which is inventoried separately. Steam locomotives, used primarily as tourist attractions, are insignificant sources (U.S. EPA 1989).

### b) Sector Description

Railroads are inventoried under SCC 24110 (Off-Highway Mobile Source - Railroads - Diesel Oil).

Diesel-electric locomotives are used in two ways: railyard switching or road-haul service. Locomotives can be further classified on the basis of engine configuration (U.S. EPA 1985):

| | |
|---|---|
| Switch locomotives: | 2-stroke (supercharged)<br>4-stroke |
| Road service locomotives: | 2-stroke (supercharged)<br>2-stroke (turbocharged)<br>4-stroke |

### c) Inventory Approach

Railroad diesel-electric locomotives are inventoried as area sources.

There are two basic methods for inventorying diesel-electric locomotive emissions. Both methods involve the use of an activity factor with an emission factor defined as a function of the activity factor.

The recommended approach uses the quantity of fuel consumed (the activity factor) and an emission factor from AP-42 (U.S. EPA 1985) in units of kg/$10^3$ litres.

The alternate approach is more complicated. This involves the derivation of work output estimates as an activity factor and the use of emission factors, in similar units, from AP-42 (U.S. EPA 1985).

## d) Preferred Emission Estimation Procedure

The most common, and cost-effective, approach to inventorying emissions from diesel-electric locomotives involves the derivation of an activity factor based on the total quantity of fuel used by all of the types of locomotives listed in Section b. This is multiplied by an average emission factor, in units of quantity of pollutant per volume of fuel burned, to derive emission estimates.

The following references are recommended:

- AP-42 (U.S. EPA 1985) for emission factors
- mobile source procedures for emission inventory preparation (U.S. EPA 1989)

AP-42 gives detailed fuel-based emission factors by locomotive engine category, in Table II-2.2, for CO, HC and $NO_x$ (as $NO_2$). These were converted into average fuel-based emission factors based on the U.S. nationwide 1972 locomotive population breakdown by category (Table II-2.1). Average $SO_x$ (as $SO_2$) and particulate emission factors are also presented in this table. The particulate emission factor is based on highway diesel data. The $SO_2$ emission factor is based on a fuel sulphur content of 0.4 percent. This emission factor can be adjusted by using the sulphur content of diesel fuel. Data on sulphur content in petroleum and synthetic fuel received by Environment Canada from 1978 to 1987 have been compiled (RTM 1988).

Ingalls (1985) has reviewed the HC, CO and $NO_x$ emission factors. It was found that rising fuel costs had led to engine improvements as well as changes in locomotive operation. Additional emission factors (to those used in AP-42) were also found in the literature. Using new duty cycles and additional emissions test data, new locomotive emission factors were developed. Environment Canada has used these updates in their most recent inventories (see Table D.45.4-1).

## d) Activity Level

Diesel fuel sales for locomotive purposes are reported by province by Statistics Canada on a quarterly basis (Statistics Canada, n.d.). These can be used for provincial inventories.

Apportionment to smaller areas can be accomplished by using track mileage data, freight density information or a population-based system. For example, ORF/MEP (1983) used a combination of the first two methods to grid Ontario $NO_x$ railroad emissions. An Economic Atlas of Ontario (Sean 1969) provided traffic levels. This information was used in combination with track distances to estimate activity levels in various grids. These were then used to apportion provincial fuel usage.
U.S. EPA (1989) gives further information on this method, although some of the sources listed are U.S. related and Canadian equivalents would have to be found.

## f) Alternative Estimation Procedures

As discussed in Section c), activity levels and emission factors may also be based on work output.

This method involves a detailed examination of the usage of rail lines to derive an activity factor based on the estimated total annual or daily horsepower-hours (work output) expended by each type of locomotive. The activity factor is then used with an emission factor specific to each type of locomotive. Although this procedure provides a more accurate and resolved emissions inventory, it is a substantial undertaking, since statistics needed for the calculation of work output can only be obtained by direct contact with the railroad company (Edwards and Cotton 1988). This method, considered to be more appropriate in small-scale inventories, was used in a study done for the Greater Vancouver area by EAG (1987).

In this method, activity factors in terms of horsepower-hours per day or year, by locomotive type, are derived for each rail line and for all switchyards and terminals. U.S. EPA (1989) gives a detailed explanation of how this is accomplished, including data requirements, data collection and activity factor calculation.

This activity factor is used with pollutant emission factors, in g/kWL output, for each locomotive type, provided in Table II-2.2 of AP-42 (U.S. EPA 1985).

### g) Temporal Variability

Province-specific temporal factors are discussed in a report by the MEP Company and Ontario Research Foundation (1985). If emissions are estimated using the work output methods, study-specific temporal factors could be derived as required and as the data permits.

### h) Geographical Variability

Methods for geographical apportionment of fuel-based emissions inventories were discussed in Section e).

Work output based inventories, by their nature, do not normally require further spatial allocation.

## TABLE D.45.4-1

### Environment Canada
### Locomotive Emission Factors
### (Environment Canada 1990)

| Pollutants | Emission Factor (kg/$10^3$L) |
|---|---|
| Particulates[1] | 3.0 |
| $SO_2$[1] | 17.0S[3] |
| $NO_x$ (as $NO_2$)[2] | 63.4 |
| HC[2] | 4.9 |
| CO[2] | 22.2 |

1. Based on AP-42 (U.S. EPA 1985)
2. Based on Ingalls (1985)
3. S = sulphur content of the fuel

## References - Section D.45.4

Dean, W.G. (Editor), 1969. "Economic Atlas of Ontario", Published for the Government of Ontario by the University of Toronto Press.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd.

Environmental Applications Group (EAG), 1987. "Lower Mainland Mobile Source Emission Inventory - Volume II: Methodology". Prepared for the Greater Vancouver Regional District.

Ingalls, M.N., 1985. "Recommended Revisions to Gaseous Emission Factors from Several Classes of Off-Highway Mobile Sources". Prepared by the Southwest Research Institute for the U.S. EPA. EPA 460/3-85-004, U.S. Environmental Protection Agency, Ann Arbor, Michigan.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report, Volume II: Appendix". Prepared for Environment Canada.

Ontario Research Foundation and the MEP Company, 1983. "Area Source Emission Inventory of Nitrogen Dioxides in Ontario". Prepared by the Ontario Research Foundation and the MEP Company for the Ontario Ministry of the Environment.

RTM Engineering Ltd., 1988. "Review of Sulphur Content of Petroleum and Synthetic Fuels". Prepared for Environment Canada.

Statistics Canada, n.d. "Quarterly Report on Energy Supply - Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources. Fourth Edition". Report No. AP-42. U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, Revised". EPA-450/4-81-026d (revised). U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

## D.45.5 AIRCRAFT (SIC 45110)

### a) General Description

Aircraft are powered by two major types of engines. The smaller aircraft usually employ reciprocating (piston) engines and the larger planes are generally powered by gas turbine engines. Both types can be further divided into sub-classes, depending on the size of the aircraft and most commonly used engine for that class (SNC and Ontario Research Foundation 1981). In Canada, the categories of aircraft that are normally inventoried are: jets, turboprops, piston-engined planes, helicopters and piston-engined planes at local airports.

In addition to aircraft emissions, every airport will have non-aircraft-originated emissions as a result of operation (off-highway mobile fuel use, plane and vehicle fueling, fuel storage, fugitive dust). While it is important that these are included in an emission inventory, they are normally included in the area source estimates for these sectors. (U.S. EPA 1989)

Particulate matter, $SO_2$, $NO_2$, CO and VOCs (also THC) are inventoried for aircraft.

### b) Sector Description

As stated above, aircraft engines are of two major categories, reciprocating piston and gas turbine.

In the piston engine, the basic element is the combustion chamber, or cylinder, in which mixtures of fuel and air are burned and from which energy is extracted by a piston and crank mechanism driving a propeller. The majority of aircraft piston engines have two or more cylinders and are generally classified according to their cylinder arrangement - either "opposed" or "radial". Opposed engines are installed in most light or utility aircraft, and radial engines are used mainly in large transport aircraft.

Almost no single row in-line or V-engines are used in current aircraft. (U.S. EPA 1985)

The gas turbine engine usually consists of a compressor, a combustion chamber and a turbine. Air entering the forward end of the engine is compressed and then heated by burning fuel in the combustion chamber. The major portion of the energy in the heated air stream is used for aircraft propulsion. Part of the energy is expended in driving the turbine, which in turn drives the compressor. Turbofan and turboprop (or turboshaft) engines use energy from the turbine for propulsion, and turbojet engines use only the expanding exhaust stream for propulsion. The terms "propjet" and "fanjet" are sometimes used for turboprop and turbofan, respectively. (U.S. EPA 1985)

Both types of engines use naphtha based jet fuel with a maximum sulphur content of 0.4 percent. (ORF 1987)

### c) Inventory Approach

Aircraft are inventoried as area sources. Emission factors, specific to the type of aircraft, operational mode and pollutant, are used in emission estimation. The specific inventory method used in Canada is different than that used in the U.S. in that both landing and take-off (LTO) cycle and inflight emissions are inventoried.

An LTO cycle includes all of the normal flight and ground operation modes such as: descent/approach (from approximately 915 metres above the ground level), touchdown, landing run, taxi in, idle/shutdown, start-up and idle, checkout, taxi out, take-off and ascent to 914 metres.

In-flight emissions occur above 915 metres.

The following SCC's are used to code aircraft emissions estimates:

| SCC | Description |
|---|---|
| 23110 | Off-Highway - Mobile Source - LTO - Jet Aircraft |
| 23120 | Off-Highway - Mobile Source - LTO - Turboprop Aircraft |
| 23130 | Off-Highway - Mobile Source - LTO - Piston Engine Aircraft |
| 23140 | Off-Highway - Mobile Source - LTO - Helicopters |
| 23150 | Off-Highway - Mobile Source - LTO - Small Piston Aircraft |
| 23210 | Off-Highway - Mobile Source - In-flight - Jet Aircraft |
| 23220 | Off-Highway - Mobile Source - In-flight - Turboprop Aircraft |
| 23230 | Off-Highway - Mobile Source - In-flight - Piston Engine Aircraft |
| 23240 | Off-Highway - Mobile Source - In-flight - Helicopters |
| 23250 | Off-Highway - Mobile Source - In-flight - Small Piston Aircraft |

### d) Preferred Emission Estimation Procedure

The following references are recommended for the development of an aircraft emissions inventory:

U.S. EPA 1985
U.S. EPA 1989

Aircraft emissions are generated by two types of activities: emissions associated with in-flight operation and emissions associated with the landing and take-off cycle (LTO).

These activities are inventoried separately for each of the five aircraft classes: jets, turbo props, piston engine planes at commercial airports, helicopters and piston engine planes at local airports.

Aircraft emissions are affected by the throttle power setting (i.e., the percentage of maximum power that the engines are producing at a given time). However, the power setting is fairly predictable, given the specific operating mode in which the aircraft is operating. The LTO cycle is the most complicated. For purposes of inventory development, five operating modes are of interest (U.S. EPA 1985):

approach
taxi/idle in
taxi/idle out
take-off
climbout

The U.S. EPA (1985) has detailed pollutant emission rates and average mode duration for each of these modes for numerous civilian and military aircraft. Environment Canada has used this data to develop emission factors for LTO cycles (emissions per LTO) and in-flight (emissions per hour) for each of the five aircraft classes specific to the Canadian situation. For LTO cycle emission factors, the average time the aircraft spends in each mode of the cycle and the corresponding emission rate are summed to arrive at a total per LTO cycle. In-flight emissions, based on emissions per hour, are classified by the type of power unit and aircraft.

The most recent emission factors used by Environment Canada are summarized in Table D.45.5-1. Periodic updates of the emission factors for each aircraft group should be done to reflect any changes in the aircraft population, since substantial differences exist between the emission factors for aircraft made by different manufacturers. (Edwards and Cotton 1988)

## e) Activity Level

Data on aircraft movements in the year of interest should be obtained from Transport Canada. These are documented in an annual report on aircraft movements such as that for 1985 (Transport Canada 1985). Additional information is available from Statistics Canada for major airports. Data for smaller airports must be obtained by contacting them directly. The number of LTO cycles for airports in the Greater Vancouver area in 1985 have been compiled by EAG (1987). These could be helpful when preparing future inventories for British Columbia (Edwards and Cotton 1988).

Provincial activity levels have been derived by Environment Canada for use in the NAPAP 1985 inventory.

### f) Alternative Emission Estimation Procedures

More detailed emission estimates can be calculated using emission factors by each type of aircraft, rather than aircraft classes. U.S. EPA (1985) lists detailed emission factors, on a kg/hr by operating mode basis, for many common aircraft models at that time. Emission factors for more recent models could be derived if emission rates by operating mode and time-in-mode information are available.

### g) Temporal Variability

Temporal factors are available on a provincial basis in a report prepared for Environment Canada by the MEP Company and Ontario Research Foundation (1985).

### h) Geographic Variability

Aircraft emissions are best spatially allocated through airport specific activity level data. Failing this, population may be used as a spatial allocation surrogate.

### i) Point Source Establishments

Not applicable.

## TABLE D.45.5-1

## Aircraft LTO Cycle and Inflight Emission Factors Derived for the 1985 Inventory by Environment Canada

| | Particulate Matter | $SO_2$ | $NO_2$ | CO | THC | VOC |
|---|---|---|---|---|---|---|
| **LTO Cycle*** | | | | | | |
| Jets | 0.622 | 1.062 | 11.290 | 22.602 | 11.344 | 11.344 |
| Turbo props | 0.480 | 1.900 | 1.320 | 2.994 | 1.094 | 1.094 |
| Piston (commercial) | 0.014 | 0.020 | 0.026 | 8.526 | 0.420 | 0.420 |
| Helicopters | 0.114 | 0.164 | 0.258 | 2.586 | 0.236 | 0.236 |
| Piston (local) | 0.012 | 0.018 | 0.022 | 6.918 | 0.226 | 0.226 |
| **In-Flight Emissions**** | | | | | | |
| Jets | 1.074 | 2.083 | 44.020 | 0.463 | 0.463 | 0.463 |
| Turbo props | 0.009 | 0.007 | 0.045 | 0.093 | 0.093 | 0.093 |
| Piston (commercial) | 0.053 | 0.042 | 0.257 | 0.524 | 0.524 | 0.524 |
| Helicopters | 0.111 | 0.080 | 0.259 | 0.241 | 0.241 | 0.241 |
| Piston (local) | 0.020 | 0.011 | 0.085 | 0.299 | 0.299 | 0.299 |

* kg/aircraft LTO cycle (unpublished)
** kg/h of flight (Environment Canada 1983)

## References - Section D.45.5

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd.

Environmental Applications Group (EAG), 1987. "Lower Mainland Mobile Source Emission Inventory - Volume II: Methodology". Prepared for the Greater Vancouver Regional District.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report, Volume II: Appendix". Prepared for Environment Canada.

Ontario Research Foundation, 1987. "General Methods for Preparing an Annual Sulphur Dioxide Emission Inventory for Sources in Eastern Canada". Prepared by Ontario Research Foundation for Environment Canada.

SNC/GECO Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fine Particulate Matter". Prepared for Environment Canada.

Transport Canada, 1985. "Aircraft Movement Statistics Annual Report". Aviation Statistics Centre.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources. Fourth Edition". Report No. AP-42. U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, Revised". EPA-450/4-81-026d (revised). U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

## D.45.6 MARINE (SIC 45400)

### a) General Description

Marine vessels include commercial or military vessels and recreational boats. Commercial or military vessels may be either steam or diesel fuel powered. Recreational boats may have either inboard or outboard engines. Emissions of particulate matter, $SO_2$, $NO_x$, THC and CO are inventoried for marine vessels.

### b) Sector Description

Commercial vessel sizes range from 20-foot charter boats to the largest tankers and military vessels. The majority of vessels in this category are powered by diesel engines or steam turbines. These are commonly called motorships (diesel) and steamships. The predominant fuel for both types is oil, both distillate and residual grades. Steamships and very large diesel engines are fueled with the heavier oils, while lighter diesel engines require distillate oil, although some residual may be added.

Recreational boats are generally less than 100 feet in length, most being less than 30 feet. Those with outboard engines are gasoline powered and usually are designed to operate on a 2-stroke cycle. Inboard engines may be either gasoline or diesel powered and tend to resemble automobile engines in terms of design, size and performance.

Further details on both of these classes may be found in U.S. EPA 1985 and 1989.

### c) Inventory Approach

Emissions from marine sources are inventoried, as area sources, under three classifications: recreational, motorships and steamships. Emissions from the latter two sources are further classified by mode of operation (underway and dockside).

Underway emissions are dependent on the power source of the vessel, the engine size, the fuel used, and the operating speed or load. Dockside emissions are related to the power requirements of the vessel for lighting, heating, pumps, refrigeration, ventilation, etc. Emissions are estimated using emission factors for particulate matter, $NO_x$, $SO_2$, VOC and CO.

The following SCCs are used:

| SCC | Description |
|---|---|
| 25110 | Off-Highway - Mobile Source - Motorships - Dockside |
| 25120 | Off-Highway - Mobile Source - Steamships - Dockside |
| 25210 | Off-Highway - Mobile Source - Motorships - Underway |
| 25220 | Off-Highway - Mobile Source - Steamships - Underway |
| 25310 | Off-Highway - Mobile Source - Gasoline Outboards |

Evaporative emissions produced during tanker loading and unloading operations or refueling a vessel are usually included in the methods presented for fuel marketing.

## d) Preferred Emission Estimation Procedure

The following references are recommended for use in preparation of appropriate emission factors for a marine inventory:

U.S. EPA 1985a
Ingalls 1985
U.S. EPA 1989

### Recreational Boats

AP-42 (U.S. EPA 1985) provides emission factors for $SO_2$, $NO_x$, HC and CO in units of g/L and g/hphr for outboard pleasure craft. Emission factors for inboard recreational boats are provided based on fuel consumption or operating time, for both gasoline and diesel engines. Particulate matter emission rates are considered to be insignificant for all classes.

Environment Canada has converted the work output based emission factors for outboard (gasoline) to g/Kwh. These are presented in Table D.45.6-1.

Steamships and Motorships

Emission factors for steamships and motorships for both dockside and underway modes were developed by Environment Canada, based on data presented in AP-42 (U.S. EPA 1985). Emissions from heavy oil were assigned to steamships while diesel fuel consumption was attributed to motorships. For dockside, EPA emission factors were available per ship per day, which were converted to an emission rate based on calls in port by obtaining an average stay in port value of 2.66 days from Transport Canada. Table D.45.6-1 summarizes these typical values.

AP-42 (EPA 1985) includes more detailed tables of emission factors for steamships based on the fuel used (residual oil or distillate oil) and the ships mode of operation (hotelling, cruise, full). The operating modes are related to the percentage of maximum power used: hotelling (10-11%), cruise (35-75%), and full (100%). Emission factors for motorships are presented on the basis of both engine horsepower and operating mode. Use of these detailed tables of emissions factors is contingent on access to details of vessel type, operating mode and, for motorships, engine size. For purposes of a provincial inventory, analysis in this detail is likely not warranted. This approach should be used for any localized analysis of high-traffic waterways. (Edwards and Cotton 1988)

A recent review (Ingalls 1985) discusses the basis for these emission factors.

### e) Activity Levels

The following is derived from Edwards and Cotton (1988).

### Recreational Boats

Statistics on the number of outboard motors in existence in each province can be determined from Statistics Canada report 64-202. A base quantity can then be approximated for outboard motors using an average size of 6.8 kW and 35-50 annual operating hours. (Environment Canada 1983, EAG 1987)

Data on the number of inboard motors are not generally available. Specific studies may be available to give this information directly or by difference between the number of outboards and total boat population. Benton (1984) and Harrison (1979) have compiled data on the number of recreational boats in the Lower Mainland of British Columbia which are of some use for inventories.

The average inboard engine size on the West Coast has been estimated at 104 kW (EAG 1987). This unit is expected to be operated at 60% load for 50 hours per year. A typical fuel consumption rate is 0.34 L/kWh.

Although specific to the U.S. situation, U.S. EPA (1989) does provide some good suggestions on other means of activity level derivation.

### Steamships and Motorships

The quantity of fuel used for commercial shipping can be established from Statistics Canada report 57-003. Statistics on ship movement are also available from the appropriate port authorities and Statistics Canada (Reports 54-203 and 54-204). Fuel consumption figures and estimates of ship travel distances can in turn be used to determine the quantity of fuel burnt underway in a study area. Fuel consumption data from the U.S. EPA (1981) and B.C. Ferries is as follows:

| | Fuel Consumption Underway (L/nautical mile) |
|---|---|
| Draft >5.5 m | 62 |
| Draft 1.8 to 3.6 m | 25 |
| B.C. Ferries | 54 |

The quantity of fuel consumed at dockside has been estimated by EAG (1987) for large draft vessels to be 2376 litres per day. An average vessel stay was estimated to be 2 to 2.66 days (Environment Canada 1983, EAG 1987). The fuel consumed at dockside can be alternately estimated from the duration of stay using data for electrical generators in vessels given in AP-42. (EPA 1985)

Again, although specific to the U.S. situation, U.S. EPA (1989) provides useful insight as to how to manipulate available activity level into a useful form.

### f) Alternative Emission Estimation Procedures

Motorships emissions may be alternately estimated by using emission factors for waterway based classifications (river, great lakes and coastal). Details on this method are provided in U.S. EPA 1985 and 1989.

### g) Temporal Variability

Information on temporal variability is available in a report by the MEP Company and Ontario Research Foundation (1985). U.S. EPA 1989 also provides some data on the temporal distribution of recreational boating.

### h) Geographical Variability

In calculating steamship/motorship emissions, Environment Canada assumes that underway navigation on the east and west coasts occurs mainly outside of Canadian territory. Therefore, underway emissions are only inventoried for Ontario and Quebec. Dockside emissions are calculated for all provinces except for Saskatchewan and Alberta.

### i) Point Source Establishments

## TABLE D.45.6-1

## Environment Canada Emission Factors for the Marine Sector[1,2]

| | PM<br>CO | $SO_2$ | $NO_x$ | THC | |
|---|---|---|---|---|---|
| Dockside (kg/Call) | | | | | |
| Motorships | 19.9 | 51.9 | 60.3 | 39.8 | 55.5 |
| Steamships | 18.1 | 917 | 241.3 | 10.9 | 0.10 |
| (West) | | 734 | | | |
| Underway (kg/$10^3$ 1) | | | | | |
| Motorships | 3.0 | 16.0S[3] | 31.0 | 7.0 | 13 |
| Steamships | 2.4 | 19.1S[3] | 6.7 | 0.10 | 0.40 |
| Outboards (g/kWh) | | | | | |
| Gasoline | - | 15.5 | 0.7 | 115.6 | 340 |

Notes:

1. PM - Particulate matter
   $SO_2$ - Sulphur dioxide
   $NO_x$ - Nitrogen oxides
   THC - Total hydrocarbons
   CO - Carbon monoxide
   S - Sulphur content (%)
2. Unpublished.
3. Sulphur levels in fuels are reported in RTM Engineering Ltd. (1988).

## References - Section D.45.6

Benton, H.J., 1984. "Recreational Moorage 1984". Department of Fisheries and Oceans, Vancouver, B.C.

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton & Associates Ltd.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10.

Environmental Applications Group (EAG), 1987. "Lower Mainland Mobile Source Emission Inventory - Volume II: Methodology". Prepared for the Greater Vancouver Regional District.

Ingalls, M.N., 1985. "Recommended Revisions to Gaseous Emission Factors from Several Classes of Off-Highway Mobile Sources". Prepared by the Southwest Research Institute for the U.S. EPA. EPA 460/3-85-004, U.S. Environmental Protection Agency, Ann Arbor, Michigan.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report, Volume II: Appendix". Prepared for Environment Canada.

RTM Engineering Ltd., 1988. "Review of Sulphur Content of Petroleum and Synthetic Fuels". Prepared for Environment Canada.

Statistics Canada, n.d. "Quarterly Report on Energy Supply - Demand". Publication No. 57-003.

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors. Volume II: Mobile Sources. Fourth Edition". Report No. AP-42. U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, Revised". EPA-450/4-81-026d (revised). U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, Michigan.

## E.02.1 PESTICIDE APPLICATION (SIC 02220)

### a) General Description

Pesticides broadly include any substances used to kill or retard the growth of insects, rodents, fungi, weeds, or microorganisms. Pesticides fall into three basic categories: synthetics, non-synthetics (petroleum products), and inorganics.

Formulations are commonly made by combining synthetic pesticides with various petroleum products. The synthetic pest-killing compounds in such formulations are labelled as "active" ingredients, and the petroleum product solvents acting as vehicles for the active ingredients are labelled "inert". Neither of these toxicological designations should be interpreted as indicators of photochemical reactivity. (U.S. EPA 1981)

Pesticide may be applied in a powder form or as a liquid spray. In either case the active ingredient is dispersed or dissolved in an inert diluent. In the case of liquid formulations, the diluent is often a petroleum-derived hydrocarbon. Liquid formulations are generally applied as a spray directly to the soil, either before emergence of the planted crop, or to the foliage and soil after emergence, or to mature vegetation such as fruit trees.

### b) Process Description

Pesticide Application (SCC 65000):
he volatiles in that portion of the pesticide application which impacts the vegetation, evaporate quite rapidly. The portion which impacts the soil will also lose the more volatile diluent liquid through evaporation. The residue remaining in the soil is the active ingredient which generally has a low vapour pressure. Not all of the soil impacting active ingredient will volatilize, as some will leach into the soil with precipitation where it may degrade or otherwise by removed from the surface soil. The emission factor for the active ingredients vary widely, depending on the physical and chemical properties of the individual pesticide. On average, based on a

study of pesticide volatilization, approximately 50% of the applied pesticide (active ingredient) will volatilize (ORTECH 1990). The emission factor for the hydrocarbon diluents can be assumed to be 1 kg/kg solvent used.

### c) Inventory Approach

Area source methodology is used for this sector. The main task in preparing a VOC emissions estimate for the application of pesticides is obtaining an estimate of the total pesticide active ingredients applied as well as the quantity of hydrocarbon solvents used as diluents. Once these data have been compiled, either on a national or provincial basis and the emissions calculated from the application data, geographical apportionment can be accomplished using the distribution of agricultural land area.

### d) Preferred Inventory Approach

Miasek (1989), as reported in CCME (1990), has compiled national total data for the use of solvents in Canada for the year 1985. (See also General Solvent Use SIC 65321; Application of Surface Coating SIC 42751; Dry Cleaning SIC 97211. The hydrocarbon solvent used as diluent in pesticide products is included in the Miasek data and these data are considered to be the most reliable available at this time. In 1985 it is estimated that 11 kilotonnes of hydrocarbon solvent were used in Canada for pesticide formulations. The total amount of the active ingredients used Canada-wide will exceed the solvent amount by a considerable margin. For example, in 1988, in excess of 7 kilotonnes of active ingredient were used for agricultural purposes in Ontario alone (Moxley 1989). While some of the pesticides may not be considered to be reactive in the atmosphere, the inventory should include all organic volatiles so that subsequent speciation of the emissions can be used to include those that are likely to enter into atmospheric reaction processes. Hence, the amounts of active ingredients used in pesticide formulation with hydrocarbon diluents must be included in the inventory process for this sector.

For most pesticides, the actual sales of active ingredient which are reported annually to Agriculture Canada, are held strictly confidential and are generally unavailable for use in an inventory study. However, there are published surveys which are conducted at a provincial level which provide data on active ingredient use. For sources of these data Khaja and Spearin (1985) should be used. This document details all the important sources of data relating to pesticide use in Canadian agriculture. These sources will permit an estimate of the active ingredient usage. Since some of the data compilations listed in this document are not produced every year, Statistics Canada data (46-216, for example) must be used to project or interpolate between years for which data are available. The Miasek solvent use data can be similarly projected to other years.

For specific data which may be obtainable from producer/formulators, Table E.02-1 provides a suggested list of pesticide industry member firms which should be surveyed.

Once use data for solvents and active ingredients have been compiled, total hydrocarbon emissions can be estimated using an emission factor of 1 kg THC/kg diluent solvent and 0.5 kg/kg active ingredient applied.

### e) Activity Level

The activity levels for the use of pesticides is implicit in the base quantities of solvent and active ingredient compiled in d).

### f) Alternative Emissions Estimation Procedure

As an alternative to a detailed compilation of pesticide use, application rate factors (kg active ingredient/ha crop) can be used. Such factors can be derived for Canadian Conditions (Ontario) using Moxley (1989). Tabulations of pesticide application rates for field crops, fruit and vegetables are provided in this reference. These rates, in conjunction with crop acreage statistics, such as are provided by Statistics Canada 22-00x, will provide an estimate of active ingredient use by crop. The Miasek (1989) data should be used for the hydrocarbon diluent, as discussed in a). The same emission factors for solvent and active ingredient, as described in d), should be used in the alternative emissions estimation method.

### g) Temporal Variability

The seasonal, annual and diurnal distributions of pesticide activity are available in MEP/ORF (1986).

### h) Geographical Variability

At the provincial level, total national emissions estimates can be apportioned using provincial total crop acreages from Statistics Canada. In order to resolve the emissions to scales which are sub-provincial, land use data which provide maps or gridded agricultural land areas, must be used. As an alternative, but less accurate method, farm labour force statistics can be used to distribute the emissions.

## TABLE E.02.1-1

## Pesticide Industry Member Firms Contacted for Sector Analysis (Trade and Commerce 1982)

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Allied Chemical Services Ltd.
Chemgro Limited (Bayer)
Chipman Inc. (CIL)
Ciba Geigy Canada Ltd.
Cyanamid of Canada Ltd.
Diamond Shamrock Canada Ltd.
Dow Chemical of Canada Ltd.
Dupont Canada Ltd.
Eli Lilly and Co. (Canada) Ltd.
Gulf Agricultural Chemicals Co. Ltd.
Hoechst Canada Inc.
Interprovincial Cooperatives Ltd.
May and Baker Canada Ltd. (Rhône-Poulenc)
Monsanto Canada Inc.
Niagara Chemical (Reichhold Limited)
Pfizer Chemicals & Genetics Ltd.
Plant Products Co. Ltd.
Rohm & Hass Canada Ltd.
Shell Canada Ltd.
Shamrock Chemicals Ltd.
Union Carbide Agricultural Products Co. In.
Uniroyal Ltd.
Velsicol Corporation of Canada Ltd.

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Canadian Council of Ministers of the Environment (CCME) 1990(a). "Control Technologies for Management of Nitrogen Oxides ($NO_X$) and Volatile Organic Compounds (VOC) in Canada; Work Sub-Group 6.4: Products Substitution and Miscellaneous Sources - VOC". Report prepared by Public Public Consultation Multistakeholder Work Sub-Groups on $NO_X$/VOC Control Technologies.

Canadian Council of Ministers of the Environment (CCME) 1990(b). "CCME $NO_X$/VOC Consultation Plan". Report to the Federal-Provincial LRTAP Steering Committee on Status of National Inventory of $NO_X$/VOCs, December 1989, Revised February 1990.

Department of Trade and Commerce (1982). "An Analysis of the Pesticide Industry in Canada".

Khaja, S.R. and M.C. Spearin (1985). "Data Sources Related to Pesticide Use in Canadian Agriculture". Report to Agriculture Canada - October 1985.

MEP Company and Ontario Research Foundation (MEP/ORF) 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Report prepared for Environment Canada.

Miasek, P.G., 1989. Esso Chemical Canada, Personal Communication to Environment Canada.

Moxley, J. (1989). "Survey of Pesticide Use in Ontario, 1988". Economics Information Report No. 89-08, Ontario Ministry of Agriculture and Food.

ORTECH International (1990). "MOE Toxic Chemical Emission Inventory for Ontario and Eastern North America". Draft report prepared for Ontario Ministry of the Environment.

U.S. Environmental Protection Agency (U.S. EPA), 1981. "Procedures for Emission Inventory Preparation. Volume III, Area Sources". EPA-450/4-81-026c. NTIS PB82-240128.

## E.04.2 SLASH BURNING (SIC 04120)

### a) General Description

Slash or prescribed burning is a controlled land management treatment used to reduce logging residues, manage forest production, control insects and minimize potential for destructive wildfires. The major pollutants resulting from slash burning are particulate matter, carbon monoxide and hydrocarbons, as well as some nitrogen oxides at lower rates since combustion temperatures are low relative to most other combustion sources. Sulphur dioxide emissions are considered to be negligible (U.S. EPA 1988).

### b) Source Description

Slash Burning (SCC 33100): The practice of prescribed burning is done by the logging industry and forestry officials to manage crown lands. Ignition or firing methods such as heading, backing, spot and flank fires are used to control fire behaviour patterns that depend mainly on the type and moisture content of the fuel to be burned and weather/wind conditions. Of the combustion phases that occur (i.e., preheating, flaming, glowing and smouldering), the smouldering phase produces greater amounts of incomplete combustion products per fuel quantity consumed than other phases. Control can be administered in this latter stage by rapidly extinguishing fires when lower layers of the fuel are moist.

### c) Inventory Approach

Emissions from burning forest slash, treated as an area source, can be calculated on a provincial basis using emission factors in conjunction with estimated amounts of slash burned. Emission factors have, in some instances, been predicted by models for various fuel types and can be applied for specific fuels (e.g., wood types) in association with the mass of the appropriate fuel consumed per hectare. It should be recognized that emission factors of the combustion product mix can vary by as much as 50% with fuel and fire conditions (U.S. EPA 1988).

## d) Preferred Emission Estimation Procedure

It is recommended to procure provincial statistics on the amounts of forest slash burned, where available. Alternatively, the quantity of slash burned has been estimated by Environment Canada (1983) based on primary forest production. Emission factors, recently compiled in AP-42 by the U.S. Environmental Protection Agency (1988), are available for particulate matter, carbon monoxide and methane/nonmethane hydrocarbons (units of kg pollutant/tonne slash) which account for: types of slash burned (e.g., broadcast logging, debris, line fire), types of fuel (e.g., hardwood, conifer, grassland), and type of fire conditions (flaming, smouldering, mixed). Estimated regional-specific factors are also provided for particulate and CO that depend on general types of fuel mixes. These factors have been derived from both field and laboratory emission testing and factors for average conditions, including $NO_x$, are also presented. It should be noted that some of these updated emission factors are significantly higher than those used in previous Environment Canada emission inventories (Environment Canada 1983).

## e) Activity Level

Where data are available, it is suggested to obtain statistics on the amount of forest slash burned by contact with Provincial Government officials involved in forest/natural resources management. For example, statistics on the extent of prescribed burning in Ontario have been compiled by the Ministry of Natural Resources (MNR 1986). Alternatively, estimates of slash quantities burned have been made by Environment Canada (1983), based on primary forest log production statistics in each province (Statistics Canada) and a conversion factor of 1 tonne slash burned per $63{,}052^3$ forest production.

### f) Alternative Emission Estimation Procedures

As reported elsewhere (Edwards and Cotton 1988), the quantity of slash burned can be estimated from the area of forest land harvested using a fuel loading factor. This factor, reported in AP-42 (U.S. EPA 1985) for unspecified forest residues, is 157 tonnes/hectare. Thus, the quantity of slash burned can be estimated from the product of the forest area harvested in each province, obtained from provincial statistics, and the fuel loading factor. It is recommended to compare data for each of the methods noted above in deriving base quantities for slash burning as a means to cross-check available information.

### g) Temporal Variability

Seasonal, daily and hourly temporal factors have been estimated and reported for emissions associated with slash burning (MEP/ORF 1985).

### h) Geographical Variability

In general, the locations of slash burning activities can usually only be estimated based upon forestland locations in each province, although data for areas burned in districts have been reported (MNR 1986).

## References - Section E.04.2

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Reported prepared for Environmental Analysis Branch, Environment Canada.

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)". Report EPS 3-EP-83-10, prepared by the Environmental Protection Programs Directorate.

Ministry of Natural Resources, Ontario (MNR), 1986. "A Statistical Supplement to the Annual Report of the Minister of Natural Resources".

U.S. Environmental Protection Agency (U.S. EPA), 1985. "Compilation of Air Pollutant Emission Factors
- AP-42". 4th Edition.

U.S. Environmental Protection Agency ()U.S. EPA), 1988. "Compilation of Air Pollutant Emission Factors - AP-42". 4th Edition, Supplement B.

## E.05.1 FOREST FIRES (SIC 05120)

### a) General Description

Forest fires (also called wildfires) release large quantities of particulate matter, CO and VOCs, and moderate quantities of $NO_X$. $SO_X$ emissions are considered to be negligible.

### b) Sector Description

The size and intensity of a forest fire depends directly on such variables as meteorological conditions, the type of vegetation involved (and moisture content) and the weight of consumable fuel per acre. (U.S. EPA 1985)

The temperature gradient, oxygen supply and burning time affect the degree of combustion in a forest fire. The size and quantity of the forest fuels, meteorological conditions and topographic features combine to change the burning patterns as the fire spreads and so different levels of combustion efficiency occur during the course of a forest fire. Accurate fuel loading estimates are considered to be essential in estimating emissions from forest fires. (U.S. EPA 1985)

The SCC for forest fires is 47100.

### c) Inventory Approach

Forest fires are inventoried as area sources of particulate matter, CO, VOCs and $NO_X$ using emission factors based on the tonnes of forest fuel burned.

### d) Preferred Emission Estimation Procedure

The emission factors presented in AP-42, Supplement B (U.S. EPA 1985) are recommended for estimating particulate matter, $SO_X$, VOC and

$NO_x$ emissions for forest fires. These emission factors are given in units of lb/ton, and so must be converted to units of kg/tonne. The 1985 NAPAP report (U.S. EPA 1989) does report an $SO_2$ emission factor of .150 lb/ton burned for forest fires (Table 4-1).

It should be noted that these emission factors are based on laboratory experiments and may not accurately estimate forest fire emissions.

### e) Activity Level

Forestry Canada does produce annual statistics on forest fires. Acres of forest burned are reported by province in "Canadian Forestry Statistics" (Statistics Canada, catalogue 25-202). These are provided to Statistics Canada by Forestry Canada.

In previous inventories (i.e., Environment Canada 1983) a conversion factor of 22 tonnes/ha has been used to convert these area statistics into mass of fuel burned. This number may not be considered representative of all regions of Canada. AP-42 does present regional wildfire fuel consumption values. These may be used, in conjunction with discussions with federal or provincial forestry ministries, to develop more appropriate regional conversion factors.

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Hourly, daily and seasonal temporal factors for forest fires are presented in a report by the Ontario Research Foundation (1983).

### h) Geographical Variability

Most provincial ministries keep data on the regional location and extent of large forest fires.

## References - Section E.05.1

Ontario Research Foundation 1983. "Area Source Emission Inventory of Nitrogen Oxides in Ontario". Prepared for the Ministry of the Environment, Province of Ontario.

Statistics Canada, annual. "Canadian Forestry Statistics". Catalogue No. 25-202.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers Tapes". EPA-600/7-89-012a. Prepared by Alliance Technologies Corporation for the U.S. Environmental Protection Agency, Air and Engineering Research Laboratory, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency, 1985. "Criteria Pollutant Emission Factors. Volume I Stationary Point and Area Sources". AP-42 4th Edition (and Supplements A and B). Environmental Protection Agency, Research Triangle Park, North Carolina.

## E.22.1 FERTILIZER APPLICATION (SIC 02290)

### a) General Description

Fertilizers are applied in granular or liquid form to minimize loss through off-site drift and post application wind entrainment. Liquid applications are solutions of ammonia and/or other soluble forms of nitrogen, potassium and phosphorus. There are no significant emissions resulting from the application of liquid forms of fertilizer.

Granular fertilizers are generally formed by priling of the molten salt (urea and ammonium nitrate for example). Once the prills have solidified, they are in some cases coated with an inert powder, such as talc or clay, to prevent caking in shipment and storage. During the handling of fertilizers at the point of application and during actual application, the coating material, as well as the particulate formed through attrition, is entrained by air turbulence and transported to distances determined primarily by the particle size distribution and the prevailing meteorology.

### b) Process Description

SCC 64000 Fertilizer Application
SCC 64100 Fertilizer Application - Ammonia Distributors

The handling and application of fertilizers is a source of particulate emission. Depending on the particular fertilizer, these particulates can constitute a primary source of ammonia and/or sulphate. Only particulate emissions are addressed in this manual.

### c) Inventory Approach

Area source methodology is used for this sector.

The emissions estimate is divided into two contributing operations:

- fertilizer handling in bulk and/or bags,
- application to the crops and lands.

In view of the range of conditions such as wind, surface soil wetness and atmospheric turbulence, which may prevail during handling and application, the particulate emissions estimate for this sector will have inherent uncertainties.

Emissions are estimated on the basis of a loss per amount of fertilizer handled and applied.

### d) Preferred Inventory Approach

Emission factors (kg particulate emitted per tonne fertilizer) for handling and application are available in Environment Canada (1983).

### e) Activity Level

The amounts of fertilizer applied according to type and form are available on a provincial basis from industry associations such as the Fertilizer Institute of Ontario (or equivalent in other provinces). Statistics Canada is another source of fertilizer sales data resulting from the 1986 Census of Agriculture (Publications 96-102 to 96-112). The most recent figures will likely be available from the former sources.

Fertilizer use data are available by type and form, for example:

anhydrous ammonia (applied in solution)
urea
ammonium nitrate
fertilizer solutions
ammonium phosphates (MAP and DAP)
ammonium sulphate

Such information permits a distinction to be made between liquid and solid applications.

### f) Alternative Emissions Estimation Procedure

None.

### g) Temporal Variability

Seasonal use of fertilizers can be inferred from monthly or quarterly sales volumes for a typical year. Such statistics are available from Statistics Canada (44-250, for example). Day of week and diurnal temporal factors are available in a previous report to Environment Canada (MEP/ORF 1985).

### h) Geographical Variability

Data on fertilizer use from the 1986 Census of Agriculture are provided for each province, by type, agricultural region and census sub-division (Statistics Canada 96-103 to -112). These data can be used to solve the emission to sub-provincial scales.

### i) Point Source Establishments

None considered for this sector.

## References - Section E.22.1

Environment Canada, 1983. "A Nationwide Inventory of Emissions of Air Contaminants (1978)", Environment Protection Service Report EPS 3-EP-83-10, pp 181.

MEP/ORF, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions". Report prepared for Environment Canada.

## E.44.1 LANDFILLS (SIC 44910)

### a) General Description

Landfill disposal sites are used for a variety of solid and liquid wastes such as:

- domestic waste
- commercial waste
- hazardous waste
- liquid waste
- non-hazardous solid industrial waste
- sewage sludge

Disposal sites may be designated to receive only one or a selection of the above waste materials. The materials deposited in the landfill are progressively covered over with soil to prevent scattering of litter by wind, to prevent scavenging by rodents and other animals, and to contain odours. The organic materials in the waste decay over a period of 20-30 years, with the evolution of mainly carbon dioxide and methane in roughly equal proportions by volume. The decay process, which is mainly anaerobic, is dependant on the type of waste and its moisture content, as well as many other factors which influence the bacterial activity.

The landfill gases move out of the landfill carrying other volatiles. In uncontrolled landfills, the gas permeates through the surface soil to the atmosphere. Landfill emissions can be controlled by placing gas collection pipes in the dump and burning the gas and associated VOCs in a flare. Gas collection can be enhanced by capping the landfill with clay or other low permeability cover. Once the landfill site has been filled to capacity, the site is closed over with soil and planted with vegetative cover. Significant gas evolution from the site will continue for 20-30 years. Those sites equipped with gas collection equipment maintain flares or other combustion equipment for as long as there is sufficient gas to burn. Gas evolution is not entirely steady, but varies with infiltration of moisture; changes in barometric pressure also modulate the gas flow as pressure changes in the void space of the landfill.

The emissions from landfills are methane and associated VOCs.

## b) Process Description

SCC 44000 Landfill Sites: There are three main sources of VOCs in landfill gas (U.S. EPA 1988):

- vaporization of solvent and other volatiles deposited with the waste
- production of volatile organics by chemical reaction
- as products of biological decomposition of waste material

Gas emission is the dominant route for VOCs to reach the atmosphere, with diffusion processes playing an insignificant role except in chemical dumps with little or no bacterial activity. Where gas is collected and flared, the emission of VOC is determined by the efficiency of the flaring or other combustion process.

## c) Inventory Approach

Area source methodology is used for this sector. Estimation methods are applicable to landfills accepting municipal waste. While chemical dumps may be sources of toxic volatiles, their contribution to anthropogenic VOC emissions is small and is not considered under this sector.

The VOC emissions estimate involves the following five steps (EAG 1984):

- estimate the per capita generation of waste that goes to municipal disposal sites

- estimate the amount of active waste in landfills using the annual disposal rate and population over a 30 year period; an appropriate decay rate is used to age the amount of active waste
- estimate the gas evolution rate based on the amount of active waste
- apply a factor to the gas rate to estimate the portion of landfill gas which constitutes VOC
- for controlled sites apply an emission factor for the VOC combustion efficiency

## (d) Preferred Inventory Approach

Waste generation rate:
Patterns of waste disposal are subject to change with changing attitudes of the public and commercial establishments towards reduction, reuse and recycling of waste materials. Home composting and other composting operations are likely to have an impact on historical statistics for per capita waste generation. The most recent, as well as historical, waste disposal rate data should be obtained from the Provincial and Federal Waste Management offices. Population statistics are available from Statistics Canada.

Active waste in landfills:
The half-life decay period of waste is variable and a value of 25 years is assumed by EAG (1984). The active waste remaining in the year to be inventoried can be estimated by accumulating the annual disposal amount over a 30 year period, after decaying with an appropriate half-life.

Gas evolution rate:
U.S. EPA (1988) provides data on typical gas generation rates for landfills, depending on whether the site is in a climatologically wet or dry region. Latitude dependance does not seem to be a dominant factor in determining decay rate.

Other data are available for Canadian conditions from Rovers et al (1977).

VOC concentration:

The VOC content of landfill gas varies widely depending on the nature of the waste. U.S. EPA (1988) provides some data showing non-methane hydrocarbon emission factors ranging from 1.3 to 56 ton per year/million tons of waste with a mean of 13.6. These emission factors should be used with caution and Provincial Ministries and Federal Environment Departments should be contacted to ascertain if recent data from Canadian sites are available.

Controlled landfills:

The amount of waste in controlled landfills can be ascertained from Provincial Waste Management offices. The emission of VOC in the post combustion gases can be estimated using NAPAP emission factors from U.S. EPA (1987). (SCC 5-02-006-1)

### e) Activity Level

The estimation of activity level is implicit in the estimate of waste disposal rate in (d) above.

### f) Alternative Emissions Estimation Procedure

In the absence of specific data, or where a coarser estimate is required, the method of EAG (1984) may be used, which uses standard factors based on historical data. An allowance for controlled landfills should be made where appropriate.

### g) Temporal Variability

Provincial Waste Management offices should be contacted to ascertain the seasonal variation of emissions from any controlled landfills with gas collection equipment. A similar variation could be assumed for uncontrolled sites. Diurnal variation is not significant.

### h) Geographical Variability

At the provincial level of resolution, population provides a distribution surrogate for the emissions. For finer scales of resolution (of the order of 50-100 km), gridded population can also be used on the assumption that waste is dumped locally and is not transported large distances. For resolutions of less than 10-20 km, the locations of active and recently closed (past 15 years) landfills should be obtained from provincial Waste Management offices. Emissions associated with populations in grids without a landfill site should be assigned to sites in adjacent grids.

### i) Point Source Establishments

Data on point source establishments are only required when gridding emissions data to a fine scale of resolution. This aspect of the estimation procedure is addressed in (h) above.

## References - Section E.44.1

Environmental Applications Group (EAG) 1984, "1980 Ontario VOC Emissions Inventory", Report prepared for the Ontario Ministry of the Environment.

Rovers, F.A., J.J. Tremblay and H. Mooij, 1977. "Procedures for Landfill Gas Monitoring and Control". Environmental Impact Control Directorate, Fisheries and Environment Canada. Waste Management Report EPS 4-EC-77-4, pp 30.

U.S. Environmental Protection Agency (U.S. EPA) 1988, "Air Emissions from Municipal Solid Waste Landfills - Background Information for Proposed Standards and Guidelines", Office of Air Quality and Standards, Draft EIS March 1988; Revised and in press to issue May 1991.

U.S. Environmental Protection Agency (U.S. EPA) 1987. "Criteria Pollutant Emission Factors for the 1985 NAPAP (National Acid Precipitation Assessment Program) Emissions Inventory. Report prepared by Radian Corporation, NTIS PB 87-198735.

## E.82.1 STRUCTURAL FIRES (SIC 82240)

### a) General Description

Significant amounts of CO, particulate matter and VOCs are emitted from building fires. Emissions of $NO_x$ are much lower, while $SO_x$ emissions are considered to be nil.

### b) Sector Description

Structural, or building fires, emit large quantities of pollutants due to rapid, incomplete combustion. Quantification of these emissions is difficult because the quantity and quality of smoke is highly dependent on the type of fuel burned. (SNC/GECO Canada Ltd. and Ontario Research Foundation 1981)

The SCC code for structural fires is 47200.

### c) Inventory Approach

Structural fires are inventoried as area sources of particulate matter, CO, VOCs and $NO_x$ using emission factors based on the number of structural fires.

### d) Preferred Emission Estimation Procedure

The emission factors used in the 1985 NAPAP Emission Inventory (U.S. EPA 1989) are recommended for estimating particulate matter, CO, VOC and $NO_x$ emissions for structural fires. These emission factors, in units of lb/fire, are taken from U.S. EPA technical tables. (U.S. EPA 1986)

### e) Activity Level (Edwards and Cotton 1983)

Annual statistics for the number and types of structural fires occurring in Canada can be obtained from "Fire Losses in Canada - Annual Report" published by Labour Canada, Office of the Fire Commissioners of Canada, in Ottawa. Fire statistics are given using the following categories: residential and assembly; institutional; business and personal service; mercantile; industrial and manufacturing; storage; special fire; and farm.

### f) Alternative Emission Estimation Procedures

### g) Temporal Variability

Hourly, daily and seasonal temporal factors for structural fires are available in a report by The MEP Company and Ontario Research Foundation (1985).

### h) Geographical Variability

Data is available on a provincial basis. Further geographical apportionment can be based on population distribution.

**References - Section E.82.1**

Edwards, W.C. and Cotton, T., 1988. "VOC Emissions Methods Manual". Prepared by B.H. Levelton and Associates Ltd. for Environment Canada.

MEP Company and Ontario Research Foundation, 1985. "Temporal Factors for 1980 National Anthropogenic Area Source Emissions. Volume I: Report. Volume II: Appendix". Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation, 1981. "A Nationwide Inventory of Anthropogenic Sources and Emissions of Primary Fire Particulate Matter". Prepared for Environment Canada.

U.S. Environmental Protection Agency (U.S. EPA), 1986. "Technical Tables to the National Air Pollutant Emissions Estimates 1940-1984". EPA-450/4-85-014. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

U.S. Environmental Protection Agency (U.S. EPA), 1989. "The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers' Tapes". EPA-600/7-89-012a. Prepared by Alliance Technologies Corporation for U.S. Environmental Protection Agency, Air and Engineering Research Laboratory, Research Triangle Park, N.C.