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Air Pollution Emissions and Control Technology: Wood Pulping Industry

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AIR POLLUTION EMISSIONS AND CONTROL TECHNOLOGY: WOOD PULPING INDUSTRY

by

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NOTE TO READERS

The federal government is empowered to publish national guidelines concerning the emission of air contaminants from sources of any class. An important part of the development of such guidelines is the preparation of a technical review of the industry or commercial sector under consideration. The review includes a geographic profile of the industrial or commercial activity, a description of the principal processes used, the identification of emissions and emission sources, and an evaluation of the available abatement technology and control strategies. It might, therefore, be considered a description of the current state-of-the-art.

This publication is the result of such a review and serves two main purposes. The first is to provide the background data necessary for establishing the federal guideline for new sources. In recommending national emission guidelines, the federal government adopts the view that new plants should achieve low emission levels through the installation of advanced control technologies at the time of initial plant construction in order to provide for minimum degradation of air quality and appropriate environmental protection for future generations of Canadians.

The second purpose is to serve as a source of information on applicable control technologies for use by provincial and municipal agencies in the development of their specific abatement programs for existing sources. Existing plants, although excluded from the guideline recommendation per se, should be subject to control on an individual basis as local conditions require. This allows provincial control agencies to weigh such variable factors as industrial density, the nature and quantities of specific plant emissions, meteorology and topography, engineering feasibility and local socio-economic conditions.

This report is the technological review of the Wood Pulping Industry.

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ABSTRACT

This report provides the technical background for the Canadian Federal Government guidelines for the wood pulping industry. The emission data presented depict conditions of this industry during 1973-74. The report includes an assessment of available emission control strategies as they could be applied to both new and existing wood pulping operations.

Emissions from kraft mills, sulphite mills and ancillary equipment have been estimated for the 1973-74 period. Annual emissions from kraft mills are estimated at 98 000 tons of particulates, 52 000 tons of total reduced sulphur (TRS) and 22 000 tons of sulphur dioxide. Sulphur dioxide emissions from sulphite mills and combustion facilities are estimated at 84 000 and 200 000 tons respectively. Particulate emissions from combustion sources are about 20 000 tons.

RÉSUMÉ

Le présent rapport fournit une assise technique au gouvernement fédéral pour dégager des lignes directrices destinées à l'industrie des pâtes à papier. Il présente des données circonstanciées sur les émissions de cette industrie en 1973-74. On y trouve aussi l'évaluation des présentes méthodes d'épuration qu'on a pu appliquer aux usines nouvelles et existantes.

On a calculé les émissions des fabriques de pâte kraft, de pâte au bisulfite et des installations auxiliaires pour 1973-74. Celles des fabriques de pâte kraft atteignent 98 000 de particules, 52 000 de soufre réduit total (S.R.T.) et 22 000 de dioxyde de soufre par an. Les émissions de dioxyde de soufre des fabriques de pâte au bisulfite et des installations de combustion sont respectivement de 84 000 et de 200 000. Les émissions de particules des sources de combustion sont d'environ 20 000.

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1.1 Purpose

The Air Pollution Control Directorate, in addressing the problem of air contaminant emissions from the wood pulping industry in Canada, has prepared national emission guidelines for this industry sector, which consist of suggested emission limits for new plants. Forming part of these guidelines is the information in this report which includes an evaluation of control strategies available to reduce emissions from existing plants. The report also contains technical and other industry information relevant to the development of the guidelines for the control of air contaminant emissions from the wood pulping industry sector.

1.2 Scope

This study pertains to air contaminant emissions from all processes associated with the production of wood pulp, including those related to the production of steam and power from the combustion of fossil fuels, bark and process wastes. These latter processes have an important relationship to pulp and paper operations; hence, emissions resulting therefrom should be considered within the guidelines developed for this industry.

Location of plants and the size, processes, products and position of the industry in the Canadian economy are discussed. Process factors associated with emissions, techniques and practices for emission control and an assessment of their effectiveness and estimated capital costs are given. Included is a review of regulations and objectives already in existence for some of the more important pulp producing areas of the world. Industry data from Canadian sources are for the period 1973-74.

Air contaminant emissions of principal concern from this industry are particulate matter, sulphur dioxide and total reduced sulphur compounds (TRS). Emissions from bleacheries are examined, however, and the situation with respect to oxides of nitrogen is also mentioned.

1.3 Information Sources

The wood pulping industry is a large and well established industry in Canada and practically all its aspects have been documented. Information has been gathered from publications such as Pulp & Paper Canada, Canadian Pulp and Paper Industry, Paper Trade Journal, Pulp and Paper International, the Journal of the Technical Association of the Pulp and Paper Industry (TAPPI) and Svensk Papperstidning; from U.S. Environmental Protection Agency (EPA) publications, from meetings, conferences and discussions, from questionnaires (both air and water), from the references to this document and from many other sources. Information from the Canadian Pulp and Paper Association has been valuable. Similar associations in other countries also provide considerable information as do the Atmospheric Quality Improvement Technical Bulletins of the National Council of the Pulp and Paper Industry for Air and Stream Improvement.

The Canadian industry descriptions and industry emission data are for the 1973-74 period. Many companies indicated in their questionnaire replies that they are planning or in the process of upgrading environmental controls. Therefore emission data will be continually changing. Where emission data are unavailable estimates have been used.

Both metric and English units are used in this report, mainly because questionnaire data and reference material are usually in English units. When English units are used in reference to quantities of pulp the short ton is used (2000 lb). Where metric units are used in reference to quantities of pulp the metric tonne is used (1000 kg). For example, 1 lb/TADP (ton of air dry unbleached pulp) is equivalent to 0.5 kg/MTADP (metric tonne of air dry pulp).

2 INDUSTRY DESCRIPTION

2.1 History

The use of wood pulp to replace rag pulp began in the mid-1800's. In Canada, the first soda* wood pulp was produced in 1864 at Windsor Mills, Quebec (1). Mechanical wood pulp was first produced commercially in 1866 at Valleyfield, Quebec (2). The first sulphite pulp was produced in 1885 in Merritton (now St. Catharines), Ontario (2) and the first kraft pulp was produced in 1907 in East Angus, Quebec (2).

The production of mechanical wood pulp, mainly for newsprint, has grown steadily from 1 090 000 tons in 1920 (3) to 8 802 000 tons in 1974 (4). Sulphite pulp production increased steadily from 654 000 tons in 1920 to 2 415 000 tons in 1955 (3). During the past 20 years, however, sulphite production has remained fairly static. Production in 1974 was 2 816 000 tons (4). Two reasons for the lack of growth of the sulphite process are the limited variety of wood species that can be pulped efficiently and the increased demand for the stronger kraft pulp. Sulphite production is expected to decline because many of the 38 mills in Canada are small and old and cannot be economically improved to meet modern environmental standards. A number of Canadian newsprint mills are installing or investigating thermomechanical pulping (TMP) as a possible replacement for chemical pulps. This process may replace a portion of the unbleached sulphite pulp now used in the manufacture of newsprint.

Kraft pulp production of 188 000 tons in 1920 (3) increased very slowly until the 1940's. However, with the introduction of chlorine dioxide (ClO_2) bleaching in 1946 (2), production increased rapidly to 9 348 000 tons in 1974 (4) from 46 mills. Total production of pulp in Canada in 1974 (including miscellaneous processes) was 21 753 000 tons (4).

Figure 1 shows pulp production in Canada from 1920 to 1974 (3, 4). Pulp capacity for individual Canadian mills is reported in Appendix A, Table 5.

The total value of pulp and paper products in Canada in 1974 was $6077 million and their total export value was $4003 million (4). The value of pulp and paper products amounted to more than 3% of Canada's Gross National Product and the export value amounted to over 12% of the country's total exports.

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* Soda pulp uses sodium hydroxide as a pulping chemical. This process has been replaced entirely by the kraft process in Canada.

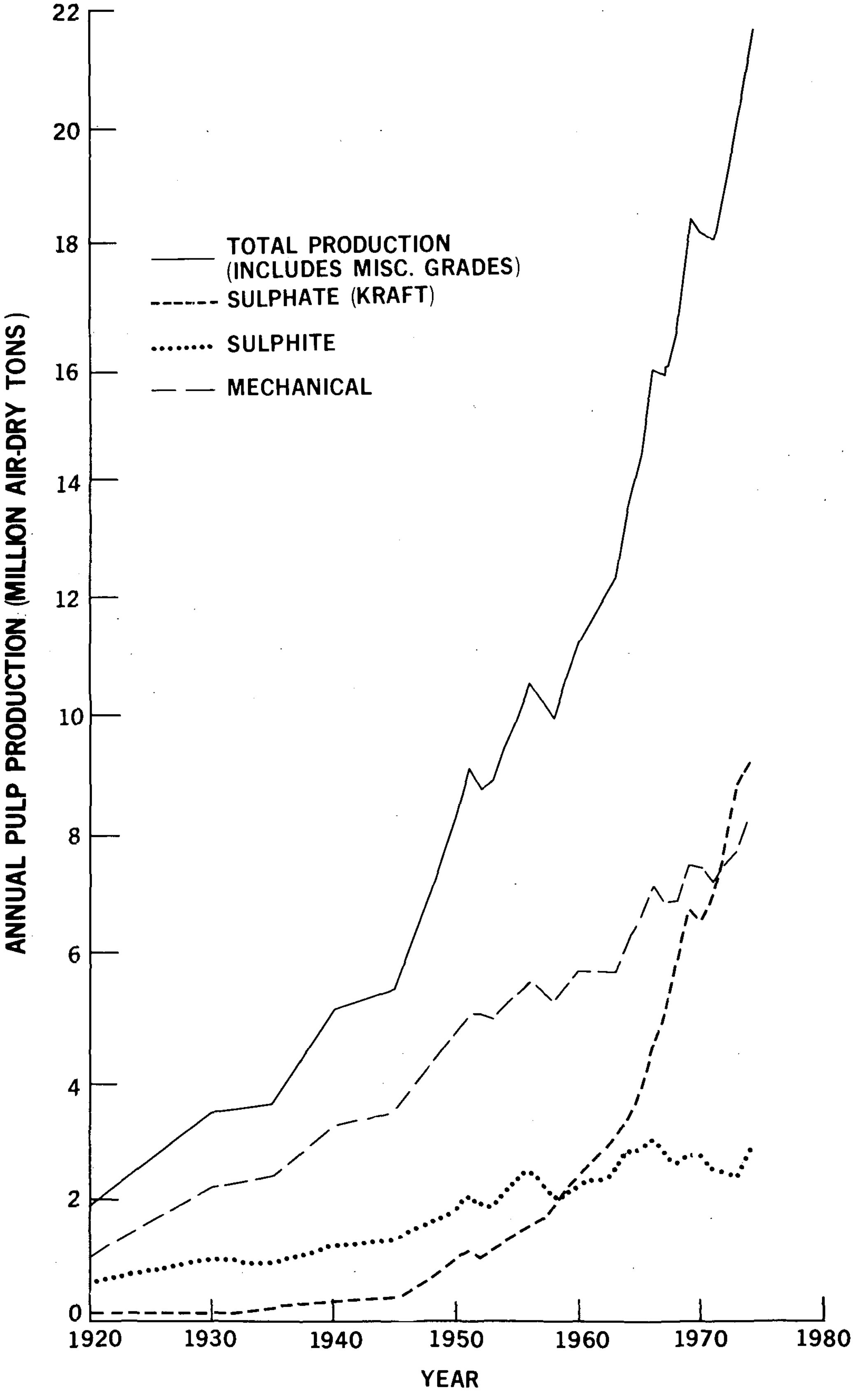

FIGURE 1 PULP PRODUCTION IN CANADA

Since World War II the industry's growth, though variable, has averaged 500 000 tons/yr (3, 4). Employment in the industry (excluding woods workers) during the last five years has varied between 75 000 and 90 000 with a 1974 employment of 87 565 (4). The salaries and wages paid in 1974 to these workers amounted to $1 111 000 000 (4). It is not easy to obtain reliable data on woods workers because of the seasonal nature of much of the work, the part-time work of farmers and others, and the difficulty in separating lumbering and pulping wood operations. Statistics Canada, however, reported data on logging employment and wages and salaries for most of Canada. In 1973 the total logging employment was 57 586 people with wages and salaries of $605 769 000 (Appendix A, Table 6). Similarly in 1973, 27 889 people were employed in the same provinces (except British Columbia) for pulpwood logging with wages and salaries of $226 780 000.

2.2 Geographic Distribution

Pulp mills were first located near sources of fresh water for power and process use and for transportation purposes. As the size of the mills grew and dependence on water for power and transportation decreased, many mills were built in remote areas near railroad lines where suitable wood was available. However, the large amounts of process water required still necessitated siting the mills near sizable streams or lakes.

On the west coast the pulp industry developed using wood residue from the lumbering industry. In recent years, the practice of using sawmill residue for pulp production has also increased in the central and eastern parts of Canada.

The consumption of water for the production of pulp has been drastically reduced over the past 20 to 30 years. Some modern kraft mills may consume less than 20 000 gal of water/ton of pulp and, as water recycling improves, this amount will continue to decrease.

Appendix D: Figures 1 to 5 show the locations of the kraft, sulphite and neutral sulphite semi-chemical (NSSC) mills in Canada. Mechanical pulp mills are often located with kraft or sulphite mills, but they are not shown in these figures because the air contaminant emissions are insignificant (5).

3 SUMMARY OF INDUSTRIAL PULPING PROCESSES

The two main processes in the wood pulping industry with significant emissions of air contaminants are the kraft process and the sulphite process with its many variations. This section presents a description of these processes, the emissions from them, the control equipment used and the levels of emissions that are reported as being attained from some of the more modern well-controlled mills. The semi-chemical process, which is usually a sulphite process, is also described briefly. The mechanical pulping process, while it is a major wood pulp producing process, is only of minor interest because the emissions are insignificant.

Significant air contaminant emissions from the wood pulping industry are particulate matter, sulphur dioxide and TRS. TRS emissions are commonly associated with kraft mills and recovery plants, and consist mainly of hydrogen sulphide, methyl mercaptan, dimethyl sulphide and dimethyl disulphide. These TRS compounds are troublesome because of their disagreeable odour and very low threshold odour level - approximately 1 ppb to 10 ppb (5).

The kraft process is a major source of TRS and particulate emissions and may be responsible for some sulphur dioxide (SO_2) emissions. TRS emissions may be in excess of 50 lb/TADP (5). However, some well-controlled new mills may be expected to have TRS emissions less than 0.50 lb/TADP (see Appendix A, Table 1).

The following processes are significant sources of TRS emission:

Recovery furnaces (including direct contact evaporators (DCE))
Digesters
Multiple effect evaporators
Lime kilns
Black liquor oxidation systems
Brown stock washers
Smelt dissolving tanks
Foul condensates and condensate stripping systems
Miscellaneous - black liquor storage tanks, sewers, etc.

The significant sources of particulate emissions from the process include the recovery furnace, the lime kiln and the smelt dissolving tank. Particulate emissions from a poorly controlled mill may be as high as 100 lb/TADP. A well-controlled mill may have less than 5 lb/TADP of emissions (Appendix A, Table 1). The total particulate emissions from kraft mills in Canada in 1972 have been estimated at 70 000 tons (6). This is 4.5% of all particulate material emitted from industrial sources in Canada. Particulate emissions from fossil-fueled power boilers are also normally associated with pulp mills.

The main source of sulphur dioxide from kraft mills is the recovery furnace. In mills with conventional recovery furnaces the DCE may be fairly efficient at controlling sulphur dioxide. Lime kilns may emit some sulphur dioxide. In Canada, in 1972, the sulphur dioxide emissions from the kraft process were estimated to be 19 000 tons, or 0.4% of the total sulphur dioxide emitted from industrial sources in the country (6).

Sulphur dioxide emissions from the sulphite process may be as high as 200 lb/TADP from a poorly controlled mill or less than 20 lb/TADP from a well-controlled mill (Appendix A, Table 1). The major emission occurs when the digesters are discharged (blown) at the end of pulping period. There may also be significant emissions from the absorption tower in the acid-making process. In 1972, sulphur dioxide emissions from this industry were estimated to be 84 000 tons, or 1.7% of the total sulphur dioxide emitted from industrial sources in Canada (6).

Particulate emissions from the sulphite process are normally limited to the recovery furnace. The scrubber used to control sulphur dioxide will also control particulate emissions, usually to less than 5 lb/TADP.

Air contaminant emissions from the Neutral Sulphite Semi-Chemical (NSSC) process, while not well documented, are considered to be minor. Some sulphur dioxide emissions result from sulphur burning for the preparation of NSSC cooking liquor. Emissions from the mechanical pulping process are considered insignificant.

Burning of bark and other organic waste for steam production is becoming more widespread as energy costs increase and other disposal methods become unsatisfactory because of space requirements or water pollution. Combination boilers that burn wood waste and other fuel are being installed for steam production in many pulp mills or lumbering operations having significant quantities of wood waste. Particulate emissions from these units can be significant and should be controlled. The uncontrolled emissions generally range between 1.5 and 2.5 gr/dscf (60-100 lb/ton of fuel). Emissions can be controlled to less than 0.2 gr/dscf (see Appendix A, Table 1).

3.1 Kraft Process

3.1.1 General. The production of kraft pulp has increased rapidly during the past 25 years. The kraft process is the most widely used pulping process today because of an efficient well-established system for the recovery and recycling of pulping chemicals and the capability of using nearly all wood species to produce a very strong pulp suitable for most end uses. All kraft pulp mills in Canada operate chemical recovery systems. The capacity of pulp mills ranges from 200 to 1500 TADP/day. Recently constructed mills have a capacity of 500 to 900 TADP/day.

Kraft pulping is accomplished by heating wood chips under pressure in an aqueous solution of pulping chemicals. The slurry of pulp fibers from the "cooking" process is washed to remove dissolved wood material and spent pulping chemicals. The dissolved wood material and spent pulping chemicals washed from the wood pulp are concentrated by evaporation and burned to produce steam and an inorganic residue. The residue or "smelt" is processed to produce pulping chemicals for recycling in the process. The fiber slurry is then screened and cleaned with centrifugal cleaners to remove knots and other contaminating material before being made into paper products. A large proportion of the wood pulp is bleached before being made into consumer products. Figure 2 shows the major elements of the kraft process.

Several steps in the pulping and chemical recovery operations may result in the production of significant quantities of emissions into the atmosphere. Efficient operation of the processes and of the emission control equipment is necessary to keep emissions at minimum levels; however, efficient operation of some parts of the process may reduce emissions to levels where emission control equipment is not required. As air and water control system efficiency improves, the possibility of transferring emissions from the original point of release increases.

3.1.2 Digesters. Kraft pulping is accomplished in large pressure vessels (digesters) - either batch or continuous - by heating wood chips in an aqueous solution containing two active chemicals - sodium hydroxide and sodium sulphide. Sawdust and shavings are also used but give pulps of lower strengths. The sodium hydroxide in the liquor is the principal pulping chemical. The sodium sulphide speeds up the removal of lignin and provides a buffering action which minimizes damage to the fibers and results in a stronger pulp than is obtained with other processes (5).

In the digester, temperatures of 170°C-180°C and pressures of 100 psig are common. From 45% to 55% of the wood (depending on the grade of pulp) reacts with the pulping chemicals to become soluble in the aqueous solution. The soluble portion consists of most of the lignin and hemi-celluloses and a little of the cellulose. The remaining

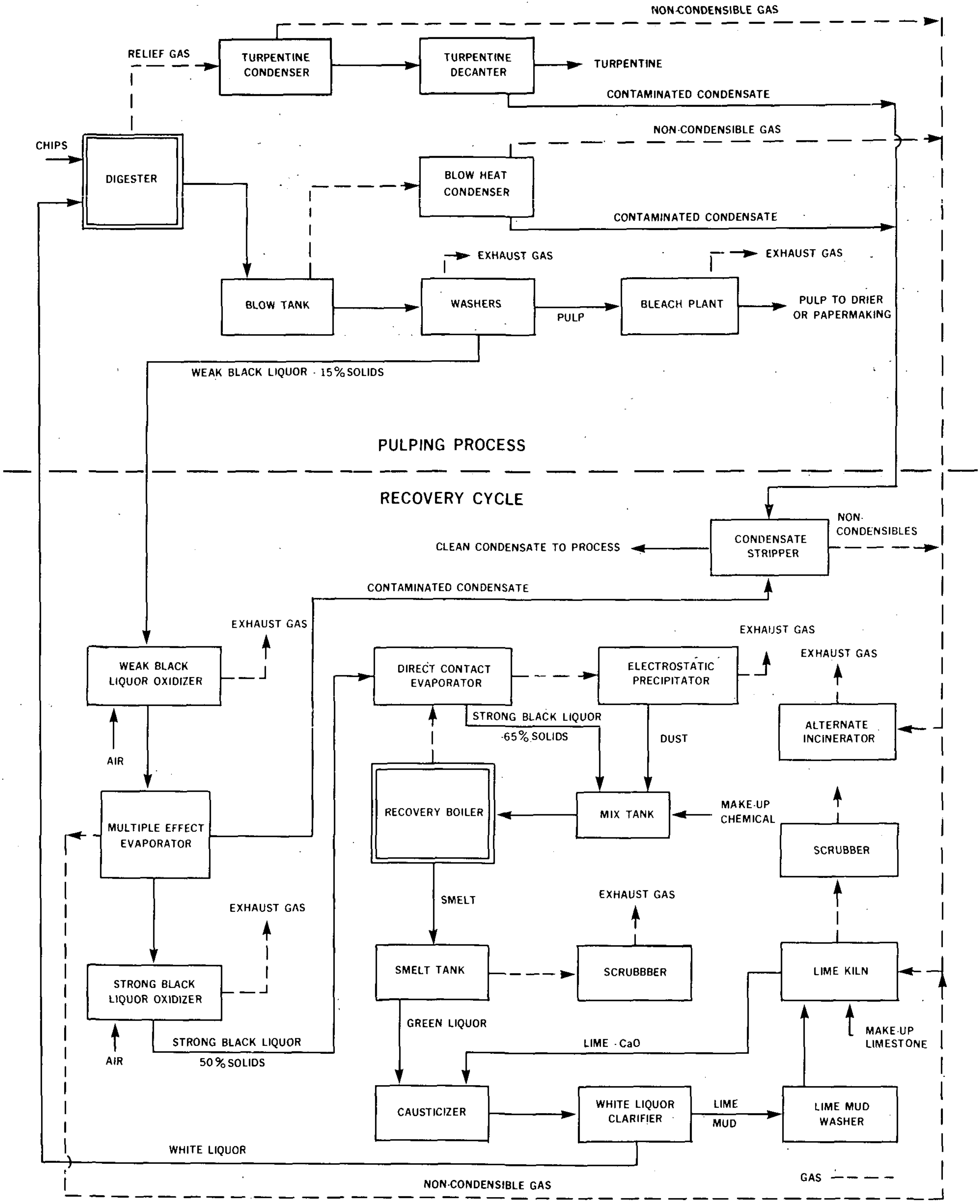

FIGURE 2 KRAFT PULPING PROCESS

portion of the wood, in the form of cellulose fibers, is the pulp. At the end of the process the digester is commonly discharged into a blow tank.

In the cooking process the sulphide ion reacts with the lignin components in the wood to produce significant quantities of TRS. Sulphidity of the pulping liquor has a major effect on the quantity of TRS produced. The digester reaction rate, which is a function of temperature and the wood species being pulped, has a limited effect on the quantity of TRS produced at this stage. Some of these compounds are released from the digester with the digester relief during the course of the cooking and some are released when the pulp is discharged from the digester at the end of the cooking period. In a batch system the periodic discharge of pulp from digesters causes surges in gaseous emissions. In a continuous digester system the release of emissions at this point is much more uniform and generally of a lower magnitude.

One method of controlling the emission of NCG (non-condensible gases) from the cooking process is by incineration* of the gases either in a lime kiln or in a special burner after most of the water and turpentine are condensed. In the batch process an accumulator may be required to regulate the flow of non-condensible gases. The advantage of incineration in a lime kiln is that most of the sulphur dioxide produced from the incineration of TRS is retained in the lime instead of being emitted into the atmosphere (5). Scrubbing the NCG with an alkaline solution is practised by some mills. The control efficiency with scrubbing will be lower than with incineration, and disposal of the scrubbing medium may be required.

The emission of TRS, reported as sulphur, from batch digesters without control systems can amount to as much as 5 lb/TADP (5). Incineration of the NCG may result in virtually complete conversion of the TRS to sulphur dioxide. Incineration (or an equivalent method), preferably in a lime kiln, is the control method suggested for both new and existing mills.

3.1.3 Knotters, Washers and Screens. Before being washed the pulp slurry from the blow tank is normally screened through coarse screens called knotters. Knotters remove uncooked knots and slivers which are usually returned to the digesters for repulping. The washing process removes the spent cooking chemical and dissolved wood material from the pulp slurry in a countercurrent operation. Commonly, there are three stages of vacuum

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* Incineration of TRS produces sulphur dioxide, but the low concentrations and quantities produced arenot generally considered to be an emission problem.

drum washers, with hot, fresh (or recycled) water being used on the showers of the third stage. The filtrates move countercurrent to the second and first stages, become weak black liquor (15% solids) when extracted from the first stage and are sent to the multiple effect evaporators in the recovery plant. Many mills with continuous digesters incorporate some washing in the digester, which replaces one or two stages of vacuum drum washers. Some recently built mills (7) have replaced the drum washers with diffusion washers. The pulp (brown stock) from the washers is further cleaned in screens and centrifugal cleaners before being bleached or made into end products. The rejects from the screens are usually defibered in disc refiners and returned to the unscreened pulp.

Sources of air contaminant emissions from this part of the process include the washer and knotter hoods, filtrate tanks, and vacuum pumps. The emissions consist mainly of dimethyl sulphide (RSR) and dimethyl disulphide (RSSR) (5).

The quantity of emissions is affected significantly by several factors. Thus, the sulphidity of the cooking liquor affects the amount of RSR and RSSR formed in cooking and subsequent process steps. Details of the process operation and equipment affect the extent to which RSR and RSSR and any hydrogen sulphide (H_2S) and methyl mercaptan (RSH) are released to the atmosphere, and the quantity of air associated with the NCG when released, for example, drum washers versus diffusion washers, degree of washing in the continuous digester, and the degree of enclosure of knotter and washer hoods. The nature of the shower water used (fresh water, clean condensate, contaminated condensate, etc.) determines whether and to what extent additional TRS gases are stripped from the wash water and added to the emissions from the spent cooking liquor. Other operating variables that are reported to affect emissions are wash water temperature, degree of agitation and turbulence in filtrate tanks and blow tank consistency (8).

The use of diffusion washers drastically reduces the quantity of washer emissions, essentially through decreasing the degree of air-liquid contact which occurs in drum washing. The incorporation of some washing in continuous digesters significantly reduces the quantity of washer emissions, as the concentration of black liquor and hence of dissolved TRS components in the final external drum washer stages is greatly reduced compared with that encountered when only drum washers are used. The use of fresh water instead of contaminated condensate also greatly reduces the washer emissions (5).

As reported (5), there is no known feasible absorption or chemical oxidation system operating for brown stock washer system vent gases containing predominantly RSR and RSSR. However, a full-scale chemical oxidation system is under construction (9). If the level of emissions is high enough to require external control, a logical method is thermal oxidation. One mill in Canada incinerates brown stock washer emissions in a recovery furnace. Control systems for these sources in the United States also use this method, with the vent gases being burned in the recovery furnace using a specially designed injection system (5, 10, 11, 12). The large volumes usually encountered make it impractical to incinerate washer system gases in a lime kiln or in a separate incinerator, and limit the existing process equipment suitable for handling such volumes to the recovery furnace or a steam or power boiler. Furthermore, the latter procedures do not appear attractive for application in any but new furnace systems because major engineering and construction changes would be required (5). Moreover, strong recommendations against using the recovery furnace for such incineration purposes have been voiced by recovery furnace manufacturers, operators and insurance representatives (13).

The emissions of TRS, reported as sulphur, from washers, knotters and screens may vary, depending on process conditions, and amount to 1 lb/TADP. Incineration of the gases, where process modifications permit, could result in virtually complete conversion of the TRS to sulphur dioxide. Limited data indicate that good operating practices may result in TRS emissions of less than 0.1 lb/TADP (Appendix A, Table 1). It is suggested that no control of this emission is required other than good operating practices.

3.1.4 Bleach Plants. The conventional bleaching operation consists of the application to the pulp of chlorine, sodium hydroxide, chlorine dioxide and/or sodium hypochlorite in four to six stages to raise the brightness* from 20% to 25% in unbleached pulp to 60% to 80% for semi-bleached pulp or 80% to 93% for fully bleached pulp. One common bleaching sequence is CEDED (Chlorination, Caustic Extraction, Chlorine Dioxide, Caustic Extraction and Chlorine Dioxide). Each stage of bleaching consists of thoroughly mixing an aqueous solution of the chemical with the pulp. The slurry is then retained for up to four hours, depending on the stage, for the chemical reaction to take place. The reactions take place at ambient or at elevated temperatures (70°C-80°C)

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* A measure of whiteness determined by a brightness meter measuring the reflecting light at a wave length of 457 mμ as compared with a block of magnesium oxide which gives a reflectance near 100%.

depending on the stage of the bleaching process. The pulp is washed on a vacuum washer between each stage. Some mills use diffusion washers instead of vacuum drum washers (7).

After bleaching, the pulp may be cleaned further (screens and/or centrifugal cleaners) before being used in making paper products in the same plant or being dried and shipped to other plants.

The only emissions of potential significance from the bleaching operation are chlorine (Cl_2) and chlorine dioxide ($Cl0_2$). Emissions may occur from the chlorine dioxide generators, the bleaching retention towers, the washer hoods and the seal tanks. A common method of control is with water or caustic spray scrubbers.

The emission of chlorine and chlorine dioxide from some chlorine dioxide generators may be significant and is commonly controlled with caustic scrubbers. Limited data are available on the actual emissions. For the remainder of the bleach plant, emission levels are not well known, but are considered small except for upset conditions.

Oxygen is used for bleaching in some mills in other countries (14). The oxygen stage may replace part of or be added to a conventional bleaching process.

3.1.5 Chemical Recovery System. The heart of the kraft pulping process is the chemical recovery system. Weak black liquor from the washers is concentrated in multiple effect evaporators. A direct contact evaporator is commonly used to recover some of the heat in the recovery furnace flue gases for part of the black liquor concentration. The concentrated black liquor is sprayed into a recovery furnace to burn the organic material and convert the inorganic portion to sodium sulphide and carbonate. The inorganic residue (smelt) from the recovery furnace is dissolved in water (or weak wash) to produce "green" liquor. The green liquor is converted to "white" liquor in the causticizing plant by reaction with calcium oxide to convert the sodium carbonate to sodium hydroxide. The resulting calcium carbonate precipitate is washed nearly free of sodium compounds and is calcined in a lime kiln to calcium oxide for re-use. The clarified white liquor is sent to the digesters for use in cooking.

The emission sources include multiple effect evaporators, black liquor oxidizers, recovery furnaces, smelt dissolving tanks, lime slakers and lime kilns.

3.1.6 Black Liquor Oxidation. When sodium sulphide in black liquor comes into contact with the carbon dioxide from the recovery furnace flue gases in the DCE, large quantities of hydrogen sulphide may be generated and stripped from the liquor and emitted into the atmosphere. This generation of H_2S can be largely eliminated by oxidizing the sodium sulphide with air or molecular oxygen to sodium thiosulphate. This oxidation may be performed before or after the MEE (multiple effect evaporators) or at both locations. In the oxidation process generally some of the TRS compounds present in the black liquor are stripped from the black liquor and emitted into the atmosphere.

The oxidation can be carried out in packed towers, plate towers or with sparging nozzles. Foaming problems occur frequently, particularly in liquors from resinous woods, and are usually more severe in weak black liquor oxidation systems. Systems have been designed with foam tanks and foam breaking equipment to minimize the problem. Weak black liquor oxidation reduces MEE corrosion, TRS emissions (5, 15, 16), and evaporator foaming, and results in less evaporator carry-over. This can be an important factor in reducing the toxicity to fish of the evaporator condensate (17). Because of the retention time through the evaporators and in storage tanks, some reversion of the oxidized sulphur compounds may occur. For this reason strong black liquor oxidation is probably required also to achieve a satisfactory level of sodium sulphide residual in the black liquor entering the DCE. Sodium sulphide residuals of 0.1 g/l or lower have been shown to largely eliminate the generation of H_2S in the DCE (5). Sodium sulphide residuals of 0.2 to 0.4 g/l have been shown to be effective at a black liquor pH of 12 (5).

TRS emissions from oxidation systems are mainly RSR and RSSR (5). The quantity of TRS emitted by these systems depends on the processing sequence, but under a combination of adverse factors may be as high as 0.5 lb/TADP. Incineration has been suggested as a control method but no systems are in operation. Limited questionnaire data indicate that TRS emissions may be less than 0.1 lb/TADP from a number of oxidizers. It is suggested that no control of this emission may be required other than good operating practice.

3.1.7 Black Liquor Concentration. In most kraft mills weak black liquor is concentrated to about 50% solids in the MEE. Further concentration to 60%-70% solids before burning then takes place in a DCE using the heat in the recovery furnace flue gas.

MEE systems normally consist of from 4 to 6 effects in series operating at pressures of from 20 psig to 40 psig in the strong liquor outlet stage to a vacuum of 25 in. to 28 in. of mercury in the condenser stage.

In the process of concentration in the MEE, non-condensible gases containing TRS are evolved from the black liquor and relieved from the evaporators.

Oxidation of black liquor before the MEE significantly reduces the TRS emissions from the evaporators. If direct contact condensers are used to maintain the MEE vacuum some of the non-condensible gases are absorbed in the water and become a source of water pollution unless they are stripped from the water. With indirect condensers, the non-condensible gases are partially absorbed in the condensate and partially relieved to the atmosphere.

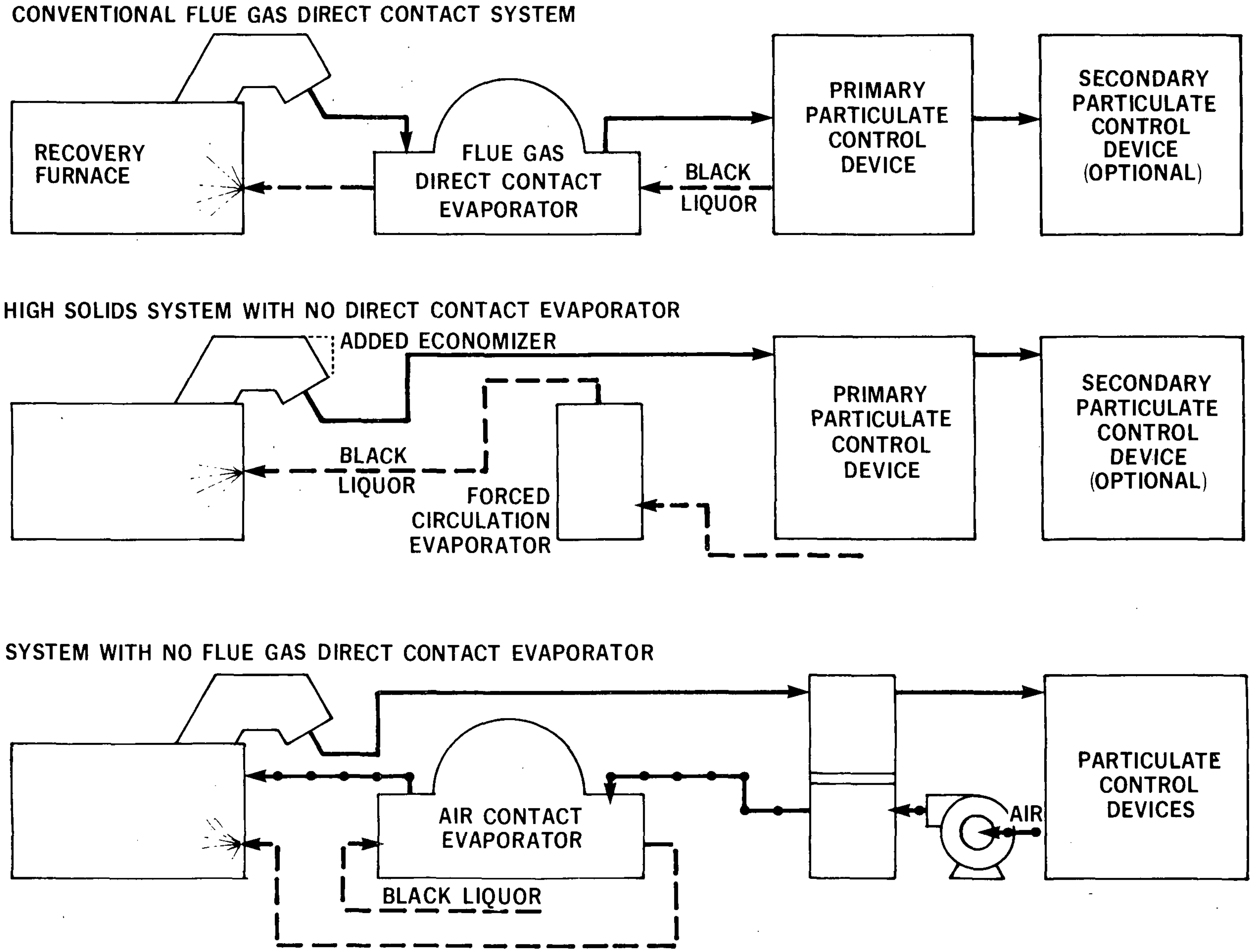
A common method of controlling the emission of the evaporator non-condensible gases is incineration. The incineration of the non-condensible gases controls the emission with virtually complete conversion of the TRS to sulphur dioxide. Incineration (or an equivalent method), preferably in a lime kiln, is the control method suggested for both new and existing mills.

DCE are standard on all recovery systems more than 5 or 6 years old in Canada. Black liquor from the MEE is contacted by the hot recovery furnace flue gas and concentrated to 60%-70% solids. The use of unoxidized black liquor may result in significant TRS emissions.

The carbon dioxide in the flue gas causes hydrogen sulphide to be generated from black liquors containing sodium sulphide. The use of adequately oxidized black liquor may reduce the TRS emissions from the DCE with an efficiency near 100%. DCE using poorly oxidized black liquor contribute to TRS emissions. DCE reduce the particulate load to the electrostatic precipitator (ESP) by approximately 50% and reduce SO_2 furnace emissions significantly. During periods of upset furnace conditions the DCE reduces TRS emissions.

The installation of "low odour" recovery furnaces has become common in Canada. In these systems the flue gas does not contact the black liquor, thus eliminating a major source of TRS emissions (Figure 3). No black liquor oxidation is needed, but additional black liquor concentration and added boiler economizer capacity are required. These systems have the disadvantage of a larger particulate load to the ESP and no emission control of the DCE during upset furnace operation.

3.1.8 Turpentine and Tall Oil. During the pulping of wood many compounds are produced and may be extracted as by-products. The more important of these are crude sulphate turpentine and crude tall oil. Since the yield of these materials varies significantly, depending on wood species, location, season and wood storage time, they are only separated and sold where the economics are favourable.


CONVENTIONAL FLUE GAS DIRECT CONTACT SYSTEM

HIGH SOLIDS SYSTEM WITH NO DIRECT CONTACT EVAPORATOR

SYSTEM WITH NO FLUE GAS DIRECT CONTACT EVAPORATOR

FIGURE 3 TYPICAL KRAFT RECOVERY FURNACE SYSTEM OPTIONS

Turpentine is collected and separated from the condensed digester relief vapours. Emissions from this operation may be incinerated with digester non-condensibles.

Tall oil, in the form of sodium salts, can be separated most efficiently from black liquor as "soap skimmings" after partial concentration. The skimmings are acidified with sulphuric acid in a tall oil plant to produce the crude tall oil and a water phase containing sodium sulphate which is returned to the black liquor. Emissions from the tall oil plant may be controlled by caustic scrubbing.

3.1.9 Recovery Furnaces. The concentrated black liquor at 60% to 70% solids from the DCE (or the forced circulation or air contact evaporator) is usually mixed with the make-up chemical (sodium sulphate, ClO_2 generator spent acid, etc.) and sprayed into the recovery furnace for burning. Figure 4 is a sketch of the furnace showing the three major operating zones. Black liquor droplets are dried as they drop through the drying and reducing zones to the smelt bed. Primary air flow must be maintained at a level to give a reducing atmosphere in the lower level of the furnace. The primary air flow also maintains a proper smelt bed temperature. If the bed temperature is too low, insufficient sodium compounds will be volatilized into the reducing zone to combine with the sulphur compounds present and higher sulphur compound emissions from the furnace will result. If the bed temperature is too high, excessive amounts of sodium compounds will be carried out of the furnace as particulate matter (18). As the gases from the combustion pass up through the oxidizing zone the introduction of secondary air permits completion of the oxidation process.

The operation and design of the furnace are very important in the regulation of emissions. With proper turbulence, bed temperature, and air distribution, essentially all the sulphur will combine with sodium and remain with the smelt, mostly as sodium sulphide. Maintaining an oxygen concentration in the flue gas of at least 2% is usually essential to maintain the TRS emissions at a minimum. If the excess oxygen is too high the formation of sulphur trioxide may give problems by causing particulate material to stick to the furnace tubes.

A number of the operating variables including the size of the droplets in the black liquor sprayed into the furnace (5, 18) are important to the control of emissions. Gross overloading or underloading of the black liquor feed to the furnace will result in an upset in the mixing and velocity of gases through the furnace so that excessive amounts of sulphur compounds will escape with the flue gas.

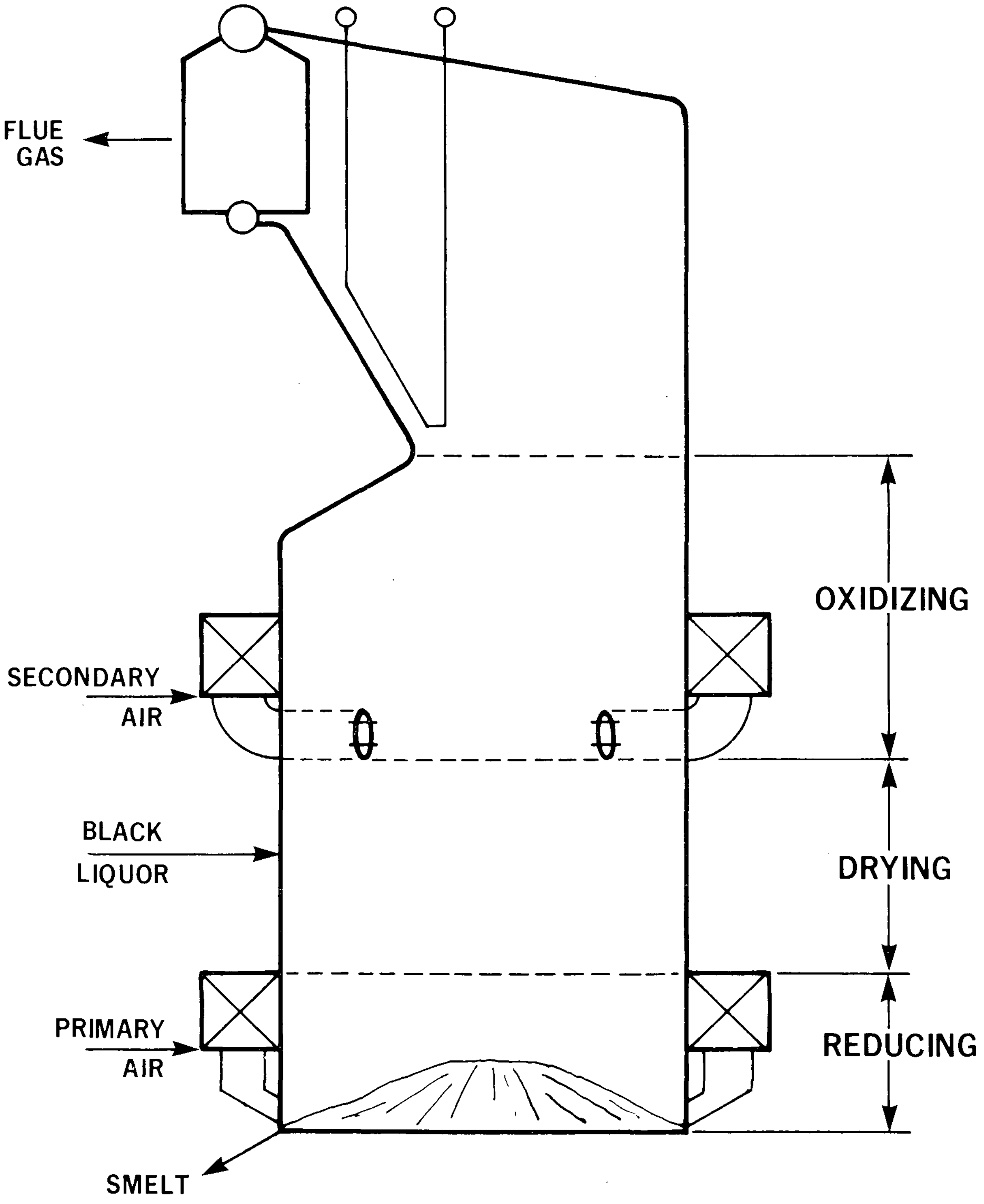


FIGURE 4 RECOVERY UNIT FURNACE ZONES

The recovery furnace is a major source of particulate emissions from the kraft mill. The particulate material is largely sodium sulphate and sodium carbonate, but in coastal areas where the wood supply is transported and stored in salt water, it may contain significant amounts of sodium chloride. The recovery of 85% to 95% of particulate emissions through the use of ESP or scrubbers is normally practiced for economic reasons. This level of efficiency combined with the DCE (section 3.1.7) will result in particulate emissions of 10-30 lb/TADP. New precipitator installations are commonly designed for particulate removal efficiencies in excess of 99%. "Low odour" recovery furnace installations require larger, more efficient ESP to achieve equal control of emissions. ESP, in practice, commonly will not meet design emission levels. In use, the efficiency tends to fall off rapidly and a large amount of maintenance is required. However, particulate emissions of less than 3 lb/TADP have been reported (Appendix A, Table 1). It is suggested that average control efficiencies of 99% for new installations and 98% for existing installations are reasonably achievable targets.

TRS stack emissions from a "low odour" recovery furnace have been reported to vary from a low of 1 ppm (11, 19) to several hundred parts per million under overloaded or upset conditions. The TRS emissions from a conventional recovery furnace under good operating conditions with a DCE and well-oxidized black liquor have been reported as low as 2 to 3 ppm (11). However, significant sampling and testing errors may be introduced when measuring TRS at these low concentrations (20).

Recently installed recovery furnaces, whether standard units using well-oxidized black liquor or "low odour" units, when operated near designed capacity should achieve TRS emissions of a few parts per million or less when using good operating practices. Units installed more than 10 to 15 years ago, because of design and instrumentation limitations, may have difficulty in achieving emissions less than 20 ppm to 25 ppm.

Sulphur dioxide emissions may vary from a few parts per million to several hundred parts per million, depending on furnace operating conditions and the type of furnace. The DCE of a conventional recovery furnace scrubs out most of the sulphur dioxide from the flue gas. For this reason a "low odour" furnace will normally have higher sulphur dioxide emissions than a conventional furnace (21). These emissions are not normally large enough to be considered a problem.

Scrubbers are sometimes used for controlling particulate emissions both separately and in series with ESP. Scrubbers are reported to remove in excess of 90% of the particulate material (5). Commercial operation has demonstrated the potential of a system using an alkaline activated carbon scrubbing medium which offers the promise of controlling both particulate and TRS emissions from many existing recovery furnaces (22, 23). Several installations using this system are in operation in the U.S.A. and one is under construction in Canada. In some areas under certain weather conditions the wet plumes from units equipped with scrubbers may result in visibility problems.

3.1.10 Smelt Dissolving Tanks. The molten smelt which runs from the smelt bed in a recovery furnace is composed mainly of sodium carbonate and sodium sulphide. This smelt drops through steam shatter sprays into a dissolving tank. Large amounts of steam are released when the smelt contacts the water and some particulate material is carried out of the stack with the steam. Packed scrubbers or mesh pads with showers may be used to control these particulates. Care must be taken in the design of the control device because of the danger of plugging. Particulate emissions are reported to be controlled to levels of 0.3 lb/TADP (see Appendix A, Table 1). It is suggested that minimum emission control for an existing installation should be by an efficiently operated mesh pad or an equivalent control device.

TRS emissions, which are usually minor, may originate from the smelt spout and weak wash in the smelt tank itself or from the shower water used in the control equipment. Emission levels of approximately 0.02 lb/TADP have been reported (Appendix A, Table 1). No control of TRS emissions appears to be required other than good operating practice.

3.1.11 Causticizers. "Green" liquor from the dissolving tank is causticized by adding lime. The lime reacts with sodium carbonate in the green liquor to produce sodium hydroxide and a precipitate of calcium carbonate. The slurry is clarified and the resulting clarified "white liquor" is used in the digesters for pulping. The lime mud (calcium carbonate) is washed nearly free of sodium compounds, thickened and conveyed to the lime kiln.

The reaction in the causticizer takes place at around 100°C. This reaction produces some steam which carries both particulate matter and TRS gases out of the vent. The emissions are not well documented, but the particulate emissions are probably small and the TRS emissions negligible.

3.1.12 Lime Kilns. The rotary lime kilns used in most kraft pulp mills are large brick-lined steel cylinders 8 ft to 12 ft in diameter and 200 ft to 300 ft long. They are inclined a few degrees from the horizontal and rotate slowly. The kiln is heated by a burner at the lower end and the washed, thickened lime mud is introduced at the upper end. The mud, together with make-up limestone, moves slowly down the kiln while the temperature is being raised to above 825°C (decomposition temperature of calcium carbonate). The high temperatures decompose the calcium carbonate to calcium oxide and carbon dioxide. The resultant lime is used in the causticizing process. The gases passing through the kiln carry particulate material (calcium and sodium compounds) and TRS to the discharge stack.

The quantity of emissions produced from the kiln depends on the efficiency of the mud washing, the temperature at the cold end of the kiln, the nature of the lime mud, the nature of the scrubbing medium and other operating conditions. A small amount of sodium compounds in the mud is desirable to help control the lime sticking to the sides of the kiln and the size of the lime balls formed in the kiln. Excessive amounts of sodium compounds in the mud cause the lime to be too sticky. Particulate matter is generated from the tumbling action of the material in the kiln and is carried along with the combustion gases. Some of the residual sodium compounds volatilize at the high kiln temperatures and are also discharged as a fume. Some of the sodium sulphide left in the lime mud after washing generates hydrogen sulphide in the presence of carbon dioxide in the flue gas and may be emitted from the kiln. Weak wash is commonly used as a source for lime mud filter shower water and lime kiln exit gas scrubber water and may be a major source of lime kiln TRS emissions.

Lime kiln particulate emissions are generally controlled with wet scrubbers. It is reported that particulate emissions can be controlled to levels of less than 1 lb/TADP (Appendix A, Table 1). Questionnaire data show the majority of mills reporting have lime kiln particulate emissions of 1 lb/TADP or less (median level 0.89 lb). It is suggested that this is a reasonable emission control level for existing kilns. Medium energy venturi scrubbers (25 in. to 30 in. of water pressure drop) can achieve this level of control.

TRS emissions may be controlled to some extent by the wet scrubbers, depending on the scrubbing medium. The use of sodium hydroxide in the scrubber significantly increases TRS removal (12). TRS levels of less than 0.05 lb/TADP have been reported (Appendix A, Table 1).

Good operating practices, including good lime mud washing and the use of non-contaminated scrubber shower water, should result in TRS emissions of 0.1 lb/TADP or less. It is suggested that additional control measures may not be required.

3.1.13 Miscellaneous. The largest single miscellaneous source of TRS emissions is probably from the stripping of contaminated condensates. Steam may be used for this stripping and the NCG produced may be incinerated in a lime kiln or separate incinerator. Incineration may result in virtually complete conversion of the TRS to sulphur dioxide. It is suggested that incineration (or an equivalent method), preferably in a lime kiln, should be the control method for both new and existing mills. If air is used for stripping, the incineration of the emissions in a power boiler or a recovery furnace has been proposed, but no established control method for the fairly large volume of gas produced is available. Air stripping should be discouraged since it may only transfer the pollution from water to air.

Vents from black liquor storage tanks and chemical effluent drains can be classified as minor sources. Sources such as screen rooms, lagoons and ponds do not normally have sufficient emissions to require control. If treatment lagoons do have odourous emissions they can usually be controlled by appropriate in-plant measures.

Materials handling can present particulate emission problems around kraft pulp mills. Lime, saltcake and wood chips are among the materials handled which may present dust problems. Newer plants have reduced the problem with enclosed handling and conveying equipment. Most of these emissions do not travel beyond the plant property. No information is available on the magnitude of these emission sources, suggesting they are normally not significant.

3.2 Sulphite Process

3.2.1 General. The sulphite process is much older than either the kraft or the NSSC processes. For this reason, most of the mills are old and small and have very little emission control equipment. Most of the sulphite mills are part of newsprint-producing plants and are located in eastern Canada. Many of them have converted from the acid sulphite process to the bisulphite process during the past 20 years. Only four new sulphite mills have been constructed in Canada during this period. Of the 38 mills operating, only four have chemical recovery systems, of which two process the spent pulping liquor to produce by-products. Most of the mills produce from 100 to 300 TADP/day; three produce over 500 TADP/day. The process is quite selective as to the wood species that can be used. The pulp produced has lower strength than kraft pulp, but it has good fiber flexibility which makes it desirable for softness (tissue) and for ease of obtaining smooth surfaces (writing paper). Processors have learned to use kraft pulp to replace most of the traditional sulphite end uses. Sulphite pulp, however, has retained its predominance in the field of dissolving pulps and for eastern Canada newsprint.

The processes involved in the production of sulphite pulp are similar to those described for kraft pulp (see Section 3.1.1). Wood chips are heated under pressure in an aqueous solution of cooking chemical to produce a fibrous slurry. The cooking chemical (acid) is usually prepared in an "acid plant" by burning sulphur and reacting the sulphur dioxide produced in an absorption tower with a solution (or slurry) of an inorganic chemical base (carbonate or hydroxide of magnesium, calcium, sodium or ammonia). The acid is fortified with sulphur dioxide relief from the digesters to give the required concentration for cooking the pulp. After cooking, the pulp slurry (or partially cooked chips in the case of a high yield system) is washed to remove the dissolved wood material and spent cooking chemicals. It is then subjected to cleaning operations to remove knots, slivers and other non-fibrous material. The higher yield pulps also require refining to defiber the chips. The major portion of sulphite produced in Canada is used without bleaching because the brightness is high enough to be used in end products such as newsprint. In most sulphite mills the spent cooking chemicals are discharged with the mill effluent resulting in major water pollution. The emissions consist mainly of sulphur dioxide. They originate in the cooking and acid-making processes. Significant differences in emissions occur, particularly from the digesters, depending on the type of sulphite process, the pulp yield and operating variables.

3.2.2 **Digesters.** Acid sulphite pulping is done in large pressure vessels (up to 10 000 cu ft) by heating wood chips in an aqueous solution of bisulphite (sodium, ammonium, calcium and magnesium are used) and sulphurous acid. A large excess of sulphurous acid is present in the cooking chemical charged to the digester at the start of the cook and is relieved to the recovery system during the cook. The presence of the excess of sulphurous acid gives very low pH values in the digester (1.0 to 1.5) and accelerates the pulping process. In the pulping reactions the bisulphite and the sulphurous acid react with the lignin and other wood materials to form soluble sulphonates. Temperatures of 130°C to 150°C and pressures of 70 psig to 110 psig are common. Pulp produced for bleached paper grade use has a yield of 45% to 50% of the wood used. For dissolving pulp grades the yield after bleaching is below 40%.

During the past 15 years "bisulphite" pulping has become widely used in the newsprint industry. This is a modified sulphite process which uses sodium or magnesium bisulphite as the cooking chemical. The cooking medium contains very little sulphurous acid and is less acid (pH 3.5-4.5) than in the acid sulphite process; therefore higher temperatures and pressures are used. The cooking reactions are more selective in removing lignin, producing a stronger pulp at slightly higher yields. Many bisulphite pulp mills, in plants producing newsprint, have converted to producing "high yield" bisulphite pulps (yields up to 75%).

There are many variations in sulphite pulping practised throughout the world. These include pulping at pH levels ranging from the strongly acid conditions of the acid sulphite pulping to alkaline conditions. The pulping may be completed in one stage, or in two or more stages, to give pulps with special properties. In Canada, few variations are used. One example is the Stora process which uses a neutral condition for the first stage followed by an acid stage.

The only emission of significance that occurs during the cooking process is the sulphur dioxide emitted during the cooking and when the digester is discharged (blown). The digester relief during the cooking operation is normally well controlled by a completely contained system of pressure vessels between the digesters and the acid plant. During the blowing of acid sulphite digesters, up to 150 lb of sulphur dioxide/TADP may be emitted into the atmosphere with steam during the sudden release of pressure from the digester to the blow tank (pit). During digester discharge the release of sulphur dioxide from the bisulphite and high yield processes is much less. If the digester is dumped* rather than blown at an elevated pressure, the emissions are significantly reduced. Many mills have separate tanks (pits) and emission stacks (vomit stacks) for each digester. Most sulphite plants have inadequate water showers in the blow tank vents to control the blowing emissions. Adequate control may require an absorption tower, by means of which the emissions can be controlled to less than 10 lb/TADP (Appendix A, Table 1).

3.2.3 Knotters, Washers and Screens.

The pulp may be washed by several diffusion washings in the blow tanks. Vacuum drum washers similar to the kraft process are also used. For high yield pulping the pulp is defibered in disc refiners as a first step. Coarse screening (deknotting) may take place before or after washing. The knots and slivers are refined for use in low-grade end products or they are discarded. After coarse screening the pulp is usually passed through fine screens and cleaned in centrifugal cleaners before being bleached or used directly in the end products. The screen rejects are refined and recycled or are otherwise disposed of.

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* Digester contents washed from the digester with waste cooking liquor after the pressure has been reduced to zero in the digester.

The only emissions resulting from these processes are sulphur dioxide. There are no data on the quantity of these emissions, but it is normally considered insignificant.

3.2.4 Bleach Plant. The unbleached brightness of sulphite pulps may be from 50% to 65%. This depends on the cooking conditions, the wood species used and the wood storage time after harvesting. This brightness is suitable for newsprint and some other end products without bleaching. However, pulp must be bleached for higher brightnesses required in fine paper for example, or for the purification required for viscose or acetate.

Sulphite pulp is more easily bleached than kraft pulp and requires less bleaching chemical and fewer bleaching stages. The bleaching operations, which are similar for both pulps, were described in section 3.1.4. Bleach plant emissions of chlorine and chlorine dioxide may be a nuisance or even dangerous to mill personnel, particularly during operational upsets. The use of water or caustic scrubbers on bleach plant vents provides satisfactory control. Limited data are available on the quantity of emissions.

3.2.5 Chemical Recovery Systems. There are more than a dozen chemical recovery systems for the sulphite process in commercial operation throughout the world. Few of these systems have similar process flows. In Canada, the four mills operating combustion units have different systems for recovering cooking chemicals. There are two mills which process spent liquor and sell the by-products. Generally only low-yield systems are considered suitable for recovery processes.

All the systems concentrate weak liquor (red liquor) from the washers in MEE. Some systems further concentrate the liquor before incineration by using the heat in the recovery furnace flue gases. Others incinerate the liquor directly from the evaporators. In the wet oxidation process no evaporation is required. Some sulphite recovery systems are complicated and descriptions may be found elsewhere (2, 24, 25).

3.2.6 Multiple Effect Evaporators (MEE). Weak red liquor, containing 9% to 15% solids, from the washers is concentrated in MEE. The maximum concentration of weak red liquor will be attained when the digesters are heated indirectly and vacuum washers are used. If red liquor from blow pit diffusion washing is used the solids concentration is 7% to 12%. MEE, of three to six effects, similar to kraft evaporators, may be used. The strong red liquor discharged from the evaporators may vary from 35% to 60% solids depending on the type of the combustion unit installation.

The only emissions of significance from the evaporators are sulphur dioxide from condensates. These emissions may amount to 10 lb/TADP (26) and may be returned to the process.

3.2.7 Liquor Combustion and Recovery Furnaces. The spent liquor combustion units may differ extensively depending on the base chemical used in cooking and other process variables. When calcium is used, the calcium is converted to calcium sulphate and calcium carbonate and some of the sulphur is oxidized to sulphur dioxide. When ammonia is used, the base chemical decomposes and the sulphur is oxidized to sulphur dioxide. When magnesium is used, magnesium oxide dust, resulting from the decomposition of magnesium compounds, is collected after combustion and the sulphur is oxidized to sulphur dioxide. Frequently when sodium is used, a smelt of molten sodium compounds results (similar to kraft liquor burning). Some of the sulphur may also be oxidized to sulphur dioxide. Sulphur dioxide in the flue gas from any of the combustion operations is recovered for reuse by scrubbing with the base chemical slurry or solution. Cooking chemical losses are made-up with sulphur dioxide (from burning sulphur or purchased sulphur dioxide) and purchased base chemical.

Sodium based liquors are burned in units similar to kraft recovery furnaces or in fluidized bed units. With a sodium based liquor, some sulphite processes convert the sodium into a form that is reusable in cooking acid by means of a complicated recovery cycle (2, 24, 25). When sodium based liquor is burned in a fluidized bed the sodium is converted to a mixture of sodium carbonate and sodium sulphate. This mixture may be used for kraft mill make-up chemical, but is not suitable for reuse in sulphite cooking. Some of the sulphur is oxidized to sulphur dioxide.

Magnesium based liquors are burned in units similar to those using sodium base except that the inorganic ash is collected as magnesium oxide dust and not as a molten smelt. With a magnesium based liquor, the magnesium is converted to magnesium oxide dust and is recycled for cooking acid manufacture. The sulphur is oxidized to sulphur dioxide.

Calcium based liquors may be burned in "add on" combustion units. These "add on" units are used with regular power boilers. The calcium is converted to calcium sulphate and carbonate and is discarded. Most of the sulphur is oxidized to sulphur dioxide. The use of calcium as a base is being phased out for a number of reasons, including its low solubility.

Ammonia based liquors are burned in units without the need to collect solids or smelt, or in "add on" combustion units. The ammonia decomposes and the sulphur is oxidized to sulphur dioxide.

The sulphur dioxide produced in any of these combustion processes is scrubbed from the flue gases along with particulates with a solution of base chemical (slurry when magnesium or calcium is used). This scrubber solution becomes cooking acid after fortification with additional sulphur dioxide. The sulphur dioxide used for fortification may be obtained from the burning of sulphur or from purchased liquid sulphur dioxide.

The control of most particulate and sulphur dioxide emissions in many of these combustion units is achieved in flue gas scrubbers which have the primary purpose of recovery of sulphur dioxide for cooking acid manufacture. Units burning ammonia base require a control device for very fine particulate removal after the scrubber. Scrubbing can reduce the particulate emission to less than 5 lb/TADP (Appendix A, Table 1). As a theoretical upper limit the uncontrolled sulphur dioxide emission could be as high as 500 lb/TADP before scrubbing. After scrubbing, this emission is reported to be less than 20 lb/TADP (Appendix A, Table 1). In the sodium base processes using recovery boilers similar to kraft recovery furnaces, no emission data are available, but the emissions are expected to be similar to those from the kraft process.

3.2.8 Miscellaneous Emission Sources. Miscellaneous emission sources emit mainly sulphur dioxide. These sources include the stripping of contaminated condensates, liquor and acid storage tanks and chemical sewers. No data are available on the level of emissions or on control methods.

Materials handling can cause fugitive dust problems around sulphite pulp mills. Wood chips, sulphur, limestone and magnesium oxide are among the materials handled which can present particulate fall-out problems. However, these tend to be local problems and no data are available on their magnitude.

The unloading and storage of chemicals such as ammonia, sulphur dioxide and chlorine will cause emissions if proper handling procedures and maintenance are not followed. Again, no emission data are available.

3.3 Miscellaneous Processes

A number of other pulping processes have been proposed and some are in commercial operation. In Canada, however, the major processes in use, other than kraft and sulphite, are mechanical pulping and Neutral Sulphite Semi-Chemical (NSSC) pulping.

The mechanical pulping processes in operation in Canada include stone groundwood and refiner pulp. In the stone groundwood process, logs are pressed against rotating cylindrical stones which rub pulp fibers from the wood. Refiner mechanical pulp

(RMP) is produced by mechanically reducing chips to fibers in rotating disc refiners. The pulps are then screened and cleaned by methods similar to the kraft process. Hydrosulphite and peroxide are used for bleaching in some operations. The emissions of air contaminants from these operations are considered insignificant (5). Several thermomechanical pulping (TMP) operations have started up. No data on emissions from this process are available, but emissions will probably be small as the yield is close to that of mechanical pulp.

NSSC pulp is usually produced by cooking hardwood chips in continuous digesters with buffered solutions of sodium sulphite or ammonium sulphite (pH 9 to 10) to yields of 70% to 80%. The cooked chips are defibered in disc refiners. The pulp may be used after defibering or screened and/or cleaned before use. Most of this pulp is used for making corrugating medium. Sulphur dioxide emissions occur from the cooking liquor preparation, and some aromatic odour is also associated with pulping process. However, emissions of air contaminants are considered minor.

4 STEAM AND POWER BOILERS

Much of the steam energy consumed by the pulp and paper industry is derived from the conventional combustion of wood waste and fossil fuels. The steam energy demand per TADP varies from 12 to 25 million Btu, depending on the production grade and process (2). This value varies from mill to mill according to the extent and condition of heat recovery equipment. Mills constructed within the last ten years exhibit a slightly lower energy demand than older mills.

The analysis of questionnaire returns which depict 1973-74 operations (Appendix C, Table 1) shows a wide national variation in the type of fuel used in the Canadian pulp and paper industry. Oil accounts for over 60% of the total fuel requirements (3.07×10^{14} Btu/yr, equivalent to 48 million barrels of oil), and varies from a high of 94% in the EPS Atlantic Region to 18% in the EPS Northwest Region. The balance of the fuel is supplied by various combinations of coal, natural gas and wood waste.

Appendix C, Table 2 shows that over 3.7 million tons (dry) of wood waste are used as fuel in this industry. The distribution across Canada shows that 58% is consumed in the Pacific Region while only 6% is consumed in the Atlantic Region. Roundwood consumption figures for these two regions are within 15% of each other (3), yet ten times more weight of wood waste is burned in the Pacific Region than in the Atlantic Region because mills in the Pacific Region are generally integrated with the lumbering operations to a greater extent than mills in the Atlantic Region. The wastes from these lumbering operations are often used to supply part of the steam required by the pulping process. This practice may not be as acceptable in Eastern Canada due to the distances involved in transporting the wood waste in some locations.

Assuming that 10% of the pulpwood consumption could contribute to wood waste, the total quantities of wood waste available from regional roundwood consumption are estimated in Table 4.1.

On a regional basis the actual wood waste consumption indicated on the questionnaire returns is generally slightly greater than the total wood waste made available from in situ pulping operations. The greatest deviations from this trend are in the Atlantic Region, where wood waste consumption is only about half of that produced by barking and chipping operations, and in the Pacific Region, where the consumption is over five times the amount of wood waste. The questionnaires from the Atlantic Region indicate several wood-waste fired installations are planned for this region to make use of the large surplus of wood waste.

TABLE 4.1 REGIONAL ROUNDWOOD CONSUMPTION

EPS Region	Roundwood Consumption 1973 million cunits	 million tons (B.D.)*	Available Wood Waste from Roundwood (tons)	Annual Wood Waste Consumption from all Sources (tons)**
Atlantic	3.81	4.56	456 000	224 000
Quebec	4.94	5.92	592 000	688 000
Ontario	3.79	4.54	454 000	450 000
Northwest	1.05	1.26	126 000	191 000
Pacific	3.30	3.96	396 000	2 218 000

* Assuming 1.00 cunit = 1.20 tons (Bone Dry).

** Appendix C, Table 2.

Appendix C, Table 3 shows the fuel types used in the mills of each region and indicates that approximately 75% of all mills burn two or more fuels. Appendix C, Tables 3 and 4 indicate that, of those mills using several fuel types, the largest number use wood waste as a fuel. Appendix C, Table 4 further shows that about half of those mills firing wood waste do so in mixed firing units. This is usually done by base loading the wood-waste boiler and demand swinging the oil-fired boiler.

Appendix C, Tables 5 and 6 indicate the national distribution of boilers in the industry by size and number. No specific trends are evident in this distribution, but over 70% of the mills in Eastern Canada (east of Manitoba) have more than three boilers per mill, while over 60% of the mills in Western Canada have fewer than three boilers per mill.

Boiler sizing is somewhat variable but the median size range seems to be design rated at 100 000 to 199 000 lb steam/h. This size range is probably representative of the older units across the country as the recent trend appears to be toward larger units in the 500 000 lb/h size range, with some units capable of 750 000 lb/h or more.

The replacement value of a package oil fired unit of approximately 200 000 lb/h is about $700 000 with no auxiliaries, and about double that amount when installed and fully operational. Larger field erected boilers range from $7 500 000 for a 300 000 lb/h unit to $12 500 000 for a combined wood-waste and oil fired 500 000 lb/h unit. The prices given for the larger units cover materials and erection only; they do not include the costs of any required buildings or structures. Smaller units designed for combination firing will cost up to $40/lb of steam/h generating capacity and the cost of wood burning, wood handling and preparation equipment will approach the cost of the furnace itself. (These prices are based on 1975 installed costs.)

4.1 Process Steam Consumptions

4.1.1 General. A survey of mills in the United States by Environmental Engineering Inc. and J.E. Sirrine Co. includes mill energy balances for the various pulping processes in the United States (26). Analysis of questionnaire returns and consultation with the Canadian Pulp and Paper Association have revealed that Canadian mills adhere closely to these balances. It is realized that the steam demand varies widely from mill to mill depending upon the electrical energy ratio, local operation, and grade and basis weight; thus a range of data for demands is included (Table 4.2) to account for these variations. The seasonal variation could also be 10% to 15% on the overall steam demand.

4.1.2 Kraft Process. The average total steam requirement per TADP of unbleached kraft is 14 000 to 20 000 lb of steam. Bleaching usually requires an additional 4 000 lb of steam/TADP.

Assuming that up to 50% of the gross steam demand for the unbleached kraft process could be met by the recovery system, the power boiler requirements average 8500 lb steam/TADP for unbleached kraft and 12 500 lb steam/TADP for bleached kraft. (The corresponding fossil fuel requirements of the power boilers could be offset by an amount equivalent to 15% of the total steam demand by burning wood waste.)

4.1.3 NSSC Process. Variation in steam demand for the NSSC process is from 14 000 to 18 000 lb steam/TADP. This demand consists of approximately 8 000 lb steam for pulping and 8 000 lb steam for drying. Wood-waste firing can reduce the fossil fuel requirements of this process by the fuel equivalent of 15% of the total steam demand.

4.1.4 Sulphite Process. Unbleached sulphite production steam requirements vary from 10 000 to 12 000 lb steam/TADP (not including the steam required for liquor evaporation). About 60% of the steam is used for pulping and 40% for pulp drying. As with the kraft and NSSC processes, wood-waste firing provides about 15% of the total steam required. Liquor evaporation in a sulphite plant where recovery is employed adds approximately 4000 lb of steam/TADP to this figure. The steam demands/TADP are summarized in Table 4.2.

TABLE 4.2 STEAM DEMAND PER TON OF AIR DRIED PULP

Process	Total Steam Demand (lb)	Fossil-Fuel-Fired Power Boiler Demand (lb)
Unbleached kraft	14 000 - 20 000	7 000 - 10 000
Bleached kraft	18 000 - 24 000	11 000 - 14 000
NSSC	14 000 - 18 000	7 000 - 9 000
Unbleached sulphite	10 000 - 12 000	10 000 - 12 000

4.2 Air Contaminant Emissions

4.2.1 **General.** The principal air contaminant emissions from fossil-fuel and wood-waste fired boilers are particulate matter and sulphur dioxide. In the absence of abatement equipment, fuel characteristics, furnace design, burner type, firing rate, fire box temperature and combustion controls are among the more important variables affecting the quantity of emissions.

4.2.2 **Particulate Emissions.** Particulate emissions from units without abatement equipment vary from 5 $lb/10^6$ Btu when lignite or high ash bituminous coals are being burned to less than 0.01 $lb/10^6$ Btu for natural gas firing. Variation of uncontrolled emissions between these limits is dependent upon the types and proportions of the fuels fired.

Bunker C oil, the most widely used fuel, can result in particulate emissions of 0.09 to 0.15 $lb/10^6$ Btu, equivalent to 0.05 to 0.09 gr/dscf at 12% CO_2.

Wood-waste fuel results in uncontrolled emissions of 60 to 100 lb of particulates/dry ton of fuel when fired alone. This is approximately equivalent to 1.5 to 2.5 gr/dscf at 12% CO_2.

4.2.3 **Sulphur Dioxide Emissions.** Sulphur dioxide emissions from units without abatement equipment vary directly with the sulphur content of the fuel being burned. The questionnaire returns indicate that the SO_2 emissions are as high as 3.5 $lb/10^6$ Btu, with an average in the range of 2 to 3 $lb/10^6$ Btu (15 to 40 lb SO_2/TADP).

4.3 Particulate Emission Abatement Equipment

4.3.1 Mechanical Collectors. The most common types of mechanical collectors employ centrifugal separation. These may either be of the multi-tube cyclone type, which exerts high centrifugal forces on the gas stream, or of the large-diameter cyclone variety.

Multiple cyclones of standard design are the most commonly used mechanical collectors for this application and are most effective for particles >10 μm and <40 μm in diameter. The particulate concentrations in the flue gases from wood-waste fired boilers using multiple cyclones under optimum conditions are typically between 0.15 and 0.25 gr/dscf. These concentrations are not necessarily valid for coastal mills where marine salts constitute a significant portion of the particulate emissions.

Capital and installation costs for multiple cyclones are about $4.00/acfm. Operating power costs vary from $0.30 to $0.40/acfm/y; this cost is based on a value of $100.00/hp/yr.

4.3.2 Wet Scrubbers. Wet scrubbers have been installed on wood-waste fired boilers as secondary collectors. The removal efficiency of these units is a function of pressure drop: with salt-free inlet loadings to the scrubber of 0.9 to 1.0 gr/dscf, low pressure drops (4 to 9 in. wg), and with pre-cleaning, outlet concentrations down to 0.1 gr/dscf are obtained. Removal of fine particulate matter requires a higher pressure drop through the unit.

Some of the problems associated with wet scrubbers are that they emit a steam plume, produce a wet sludge and contaminated water which must be disposed of, may be subject to corrosion depending on the operating conditions, and require considerably higher maintenance than mechanical collectors.

Typical capital and installation costs for wet scrubbers vary from $5.00 to $7.00/acfm. Operating power requirements are in the range of $0.35 to $0.45/acfm/yr.

4.3.3 Electrostatic Precipitators (ESP). ESP have been traditionally used on recovery furnaces and coal fired boilers. Emission levels below 0.1 gr/dscf can be achieved with most coals and lignites of less than 15% ash content.

Performance data for ESP operation on wood-waste fired units are limited. Most of the information is derived from pilot units installed on the West Coast. Pilot tests indicate that an ESP can consistently reduce particulate emissions to less than 0.10 gr/dscf with salt-free fuel. This limit is difficult to achieve consistently using a salt-containing fuel as the operational efficiency is considerably lower than on salt-free flue gas. Plate cleaning with salt-containing fuel is difficult and the increased rapping found necessary is deemed detrimental to ESP life. Also, the high resistivity of salt restricts operating voltage, thus affecting the performance.

Carbon in the fly ash from these boilers is believed to affect the performance of the precipitators. Carbon is a good conductor and can easily lose electrical charge. When a particle of high carbon content precipitates on the collector plate of an ESP, it loses its charge immediately and becomes easily subject to re-entrainment in the gas stream.

Capital and installation costs for ESP are $6.00 to $10.00/acfm, with operating power costs between $0.25 and $0.35/acfm/yr.

4.3.4 **Dry Bed Scrubber.** The dry bed scrubber is a relatively new concept for application to wood-waste fired boilers. Test data have been obtained from four pilot-scale installations and operating data are available from one full-scale unit. The data indicate that dry scrubbers are capable of achieving levels as low as 0.10 gr/dscf consistently on salt-free fuels whereas, with high salt-content fuels, this level is not achieved on a consistent basis. Further test results from a full-scale operation are necessary before a proper evaluation of this type of equipment can be made.

Estimated capital and installation costs for dry scrubbers vary from $6 to $8/acfm, with operating power costs between $0.25 and $0.35/acfm/yr.

4.3.5 **Summary.** The various types of collectors discussed in the preceding paragraphs are summarized in Table 4.3. This summary represents the most common particulate collection devices currently available, operating on combination fired boilers.

TABLE 4.3 SUMMARY OF PARTICULATE COLLECTORS

Type of collector	Capital cost installed $/acfm	Power costs $/ acfm/yr	Typical Performance gr loading gr/dscf INLET	OUTLET
ESP	6.00 - 10.00	0.25 - 0.35	0.2-0.5	Less than 0.10*
Dry Scrubber	6.00 - 8.00	0.25 - 0.35	1.5-2.0	Down to 0.10*
Wet Scrubber	5.00 - 7.00	0.35 - 0.45	0.9-1.0	Down to 0.10
Multiple Cyclone	3.00 - 8.00	0.30 - 0.40	1.5-2.0	0.15-0.25

* Salt-free fuel.

4.4 Abatement of SO_2 Emissions

4.4.1 **General.** Questionnaire returns indicate that the liquid fuels most widely used in power boilers have sulphur contents between 2.5% and 3.0% by weight. The control of SO_2 emissions associated with the combustion of these fuels may be improved by:

1) fuel blending with low-sulphur fossil fuel;
2) flue gas scrubbing to remove SO_2, as used primarily in American power industry;
3) increase in wood-waste combustion.

4.4.2 **Comparative Fuel Costs.** Fuel oil costs (April 1976) and sulphur contents were obtained for the industry across Canada (Table 4.4).

TABLE 4.4 REGIONAL FUEL OIL COSTS (APRIL 1976)

Region	Fuel Type	Cost $/Imp. Gal.	Sulphur Content % by weight	Calorific Value Btu/Imp. Gal.	Energy Cost $/10^{6}Btu
Pacific Coast	No.6	$0.24	1.75 - 2.0	171 500	$1.40
	No.2	0.36	0.16 - 0.34	154 800	2.33
B.C.Interior and Prairies	No.6	0.322	1.75 - 2.0	179 280	1.80
	No.2	0.42	0.16 - 0.34	162 380	2.59
Ontario	No.6	0.27	2.5 - 3.0	179 000	1.50
	No.2	0.436	0.3 - 0.5	162 380	2.68
Quebec	No.6	0.19	2.5 - 3.0	179 000	1.06
	No.2	0.37	0.4 - 1.0	165 000	2.24
Maritimes	No.6	0.26	2.5 - 3.0	185 000	1.41
	No.2	0.42	0.3 - 0.6	161 500	2.60

4.4.3 **Oils.** The incremental cost of switching from the fuel oils currently used for power boilers in the industry (Appendix C, Table 3) to low sulphur fuel oil blends varies with the region and the sulphur level desired.

Sulphur emissions could be reduced to the equivalent of those which would result from the combustion of 1.0 % sulphur by weight fuel oil by using a blend of No. 2 and No. 6 oils. In the western regions, a blend of 46% No. 6 and 54% No. 2 would be required (Table 4.4). This blend costs $0.30/imperial gal or $1.83/10^{6}Btu. Eastern regions, including Ontario, would require a blend of 80% No. 2 oil, at a cost of \$0.35/imperial gal or \$2.07/10^6Btu. The incremental cost to the industry would average \$0.13/10^6Btu (\$1.83 to \$1.70) in western regions and \$0.80/10^6Btu (\$2.07 to \$1.27) in the eastern regions. The above energy cost is weighted on the basis of the No. 6 fuel consumption and cost in each region.

Questionnaire returns indicate that the fuels being burned in western regions contain less than 2.0% sulphur by weight, whereas in the eastern regions the fuel sulphur content is in the 2.5% to 3% range by weight. An incremental cost of about \$0.15/10^6Btu would be incurred in the eastern regions in attaining a 2.0% wt fuel sulphur content. These calculations assume a constant price differential between No. 2 and No. 6 oils and are subject to local fuel price variations. Fuel availability has not been examined.

The cost impact on a production basis can be shown from the data in Table 4.2 and the regional cost figures given in this section. This analysis indicates only the magnitude of the cost impact on a regional basis; individual mill costs could vary significantly from the mean values given in Table 4.5.

TABLE 4.5 ECONOMIC IMPACT OF FUEL OIL BLENDING

		Incremental Cost \$/TADP			
	Steam Energy	1% Sulphur Content		2% Sulphur Content	
Process	10^6 Btu/TADP	East	West	East	West
Unbleached kraft	7 - 10	5.60 - 8.00	.91 - 1.13	1.05 - 1.50	-
Bleached kraft	11 - 14	8.80 - 11.20	1.43 - 1.82	1.65 - 2.10	-
NSSC	7 - 9	5.60 - 7.20	.91 - 1.17	1.05 - 1.35	-
Unbleached Sulphite	10 - 12	8.00 - 9.60	1.13 - 1.56	1.50 - 1.80	-

4.5 SO_2 Flue Gas Scrubbing Systems

The SO_2 scrubbing equipment is an alternative for reducing SO_2 emissions from power boilers. Various processes for flue gas scrubbing have been developed and installed on boilers in the American utility industry. One of the most highly developed systems for the boiler size range under consideration (25 to 60 MW; SO_2 emissions - 1000 ppm) is the wet limestone scrubbing process, which usually provides both SO_2 and particulate removal from flue gases of 70% to 90% efficiency.

The SO_2 and particulate removal efficiencies are dependent upon the pH of the scrubbing liquor, the liquid-to-gas ratio, the gas residence time, the pressure drop across the system, and the gas velocity. U.S. experience has shown system availability varies from 50% to 90% of the boiler running time. Good reliability has been reported from systems operating on oil fired units installed in Japan.

Capital and installation costs for SO_2 stack-gas scrubbing equipment vary from $8000 to $10 000/1000 lb/h unit steam capacity. Operating costs are more difficult to evaluate because they depend upon the site-specific costs of chemicals, sludge handling, electrical power and water. Annual operating costs could range from $3200 to $6400/1000 lb/h steam capacity, and operating labour requirements could be as high as 4 man-years/installation.

For a typical 1000 ton/day mill with a fossil-fuel fired boiler steam demand of 600 000 lb/h, capital and installation costs of SO_2 scrubbing equipment would be $4.8 to $6.0 million, with an annual operating cost of $1.92 to $3.84 million ($6.50 to $17.00/TADP). These amounts reflect the costs of chemicals but not sludge disposal (8 lb sludge/lb SO_2 removed). Maintenance has been estimated at 5% of the capital expenditure.

5 INDUSTRY QUESTIONNAIRE DATA

An emission questionnaire*, drafted by the Air Pollution Control Directorate, was reviewed by the Canadian Pulp and Paper Association environmental services group and by the provincial environmental agencies. The questionnaire, requesting information on equipment, process and emissions, was sent to plants in Canada producing wood pulp. A summary of the emissions is shown in Appendix B, Table 1.

5.1 Air Contaminant Emission Summary - Kraft Mills

5.1.1 Recovery Furnaces. Particulate emissions are reported from 39 mills (Appendix B, Table 1.1). The average emission is 17.3 lb/TADP with a median level of 9.0 lb/TADP. The maximum and minimum particulate emissions reported are 108 and 0.7 lb/TADP. For comparison, Appendix A, Table 1 indicates that control of emissions to a level of less than 3 lb/TADP has been reported. Questionnaire data show four mills reporting levels at or below this level.

TRS emissions are reported from 31 mills (Appendix B, Table 1.1). The average emission is 7.87 lb/TADP with a median level of 2.7 lb/TADP. The maximum and minimum TRS emission levels are 41.4 and 0.014 lb/TADP. For comparison, Appendix A, Table 1 indicates that emission levels of less than 0.2 lb/TADP from standard recovery furnaces and less than 0.1 lb/TADP from "low odour" furnaces can be attained. Questionnaire data show three mills reporting TRS emissions at or below these levels.

Sulphur dioxide emissions are reported from 21 mills (Appendix B, Table 1.1). The average emission is 4.2 lb/TADP with a median level of 2.4 lb/TADP. Maximum and minimum levels reported are 25.6 and 0.2 lb/TADP.

An examination was made of the recovery furnace questionnaire data (including DCE) to determine the effect of oxidation systems and overloading on the emission of TRS. Nine mills reporting with black liquor oxidation (BLO) systems and no significant overloading have average TRS emissions of 1.8 lb/TADP. Nine mills with BLO systems and furnaces operating at greater than 10% overload have average TRS emissions of 6.3 lb/TADP. With no BLO and no significant overload, four mills report an average TRS emission of 13.5 lb/TADP. With no BLO and a significant overload for five mills the average TRS emission is 25.1 lb/TADP. A correlation of TRS emission versus Na_2S in the

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* Copies of the questionnaire are available on request from the Air Pollution Control Directorate, Environment Canada, Ottawa, K1A 1C8.

black liquor entering the DCE shows a positive relationship. Four "low odour" furnaces with no significant overload report an average TRS emission of 0.1 lb/TADP. No overloaded "low odour" recovery furnaces were reported.

5.1.2 Smelt Dissolving Tanks. Particulate emissions are reported from 28 mills (Appendix B, Table 1.2). The average emission is 1.96 lb/TADP with a median level of 1.2 lb/TADP. The maximum and minimum levels are 8.3 and 0.04 lb/TADP. For comparison, Appendix A, Table 1 indicates that control of particulate emissions to a level of less than 0.3 lb/TADP has been reported. Questionnaire data show three mills reporting emissions at or below this level.

TRS emissions from smelt dissolving tanks are reported from 24 mills (Appendix B, Table 1.2). The average emission is 0.08 lb/TADP with a median level of 0.06 lb/TADP. The maximum and minimum levels are 0.5 and 0.004 lb/TADP.

A sulphur dioxide emission of 0.3 lb/TADP is reported by one mill (Appendix B, Table 1.2).

5.1.3 Causticizers. Particulate emissions are reported from four mills (Appendix B, Table 1.3). The average emission is 0.5 lb/TADP with a maximum and minimum level of 1.5 and 0.009 lb/TADP.

TRS emissions are reported from six mills (Appendix B, Table 1.3). The average emission is 0.002 lb/TADP with a maximum and minimum level of 0.007 and 0.0001 lb/TADP.

5.1.4 Lime Kilns. Particulate emissions are reported from 35 mills (Appendix B, Table 1.4). The average emission is 1.45 lb/TADP with a median level of 0.89 lb/TADP. The maximum and minimum levels reported are 12.7 and 0.08 lb/TADP. For comparison, Appendix A, Table 1 indicates that control of emissions to a level of less than 1 lb/TADP has been reported. Questionnaire data show this level of emission or lower is reported to be obtained by 22 mills.

TRS emissions are reported from 26 mills (Appendix B, Table 1.4). The average emission is 0.24 lb/TADP with a median level of 0.18 lb/TADP. The maximum and minimum levels reported are 3.07 and 0.002 lb/TADP. For comparison, Appendix A, Table 1 indicates that emissions of less than 0.05 lb/TADP have been reported. Questionnaire data show emissions at or below this level are reported by seven mills.

Sulphur dioxide emissions are reported by 12 mills (Appendix B, Table 1.4). The average emission is 0.51 lb/TADP with a median level of 0.17 lb/TADP. The maximum and minimum levels reported are 4.0 and 0.01 lb/TADP.

5.1.5 Digesters. TRS emissions are reported from five mills (Appendix B, Table 1.5). The average emission is 1.76 lb/TADP with a median level of 0.86 lb/TADP. The maximum and minimum levels reported are 4.5 and 0.24 lb/TADP. Questionnaire data show nine mills incinerating the digester relief. The incineration should result in virtually complete conversion of the TRS to sulphur dioxide. Eight mills control the emissions to some extent by venting through BLO systems, by wet scrubbing or by some other odour control system. Some mills have a number of emission points from the digester systems. Since not all these points are measured for all mills, some results may be low.

5.1.6 Knotters and Washers. TRS emissions are reported from 18 mills (Appendix B, Table 1.6). The average emission is 0.19 lb/TADP with a median level of 0.13 lb/TADP. The maximum and minimum levels reported are 0.78 and 0.02 lb/TADP. Questionnaire data show that one mill incinerates these gases. Three mills reported controlling these emissions by combining them with bleach plant emissions or by such methods as scrubbing or venting through BLO. In most mills there are a number of emission points around the knotters and washers. Since emissions from all these points may not be measured in all cases, some results may be low.

5.1.7 Black Liquor Oxidation. TRS emissions are reported for nine mills (Appendix B, Table 1.7). The average emission is 0.15 lb/TADP with a median level of 0.10 lb/TADP. The maximum and minimum levels reported are 0.56 and 0.03 lb/TADP. Eight of the nine plants reporting operate weak BLO systems. The data are insufficient to indicate differences in emissions between weak and strong systems. Fifteen mills with conventional recovery furnaces have no BLO systems. Two mills vent the emissions to the direct contact evaporators.

5.1.8 Multiple Effect Evaporators (MEE). TRS emissions are reported for 10 mills (Appendix B, Table 1.8). The average emission is 0.89 lb/TADP with a median level of 0.63 lb/TADP. The maximum and minimum levels reported are 2.4 and 0.06 lb/TADP. Questionnaire data show that nine mills incinerate the MEE emissions and three mills control these emissions by such methods as venting through the BLO or by scrubbing.

5.1.9 Bleach Plants. Chlorine emissions from bleach plants are reported from six mills (Appendix B, Table 1.9) with an average level of 1.0 lb of Cl_2 /TADP. Maximum and minimum levels reported are 4.8 and 0.01 lb of Cl_2/TADP. Chlorine dioxide emissions are reported from six mills with an average level of 0.29 lb of ClO_2/TADP. The maximum and minimum levels reported are 0.5 and 0.0005 lb of ClO_2/TADP. Three mills report Cl_2 and ClO_2 together and give an average level of 0.07 lb/TADP. Most bleach plants have a number of emission points, but not all of them were measured; therefore the results shown are probably low.

5.1.10 Chlorine Dioxide Generators. Emissions from chlorine dioxide generators are reported separately for four mills (Appendix B, Table 1.10). The average level of chlorine emitted is 0.4 lb/TADP and of chlorine dioxide is 0.25 lb/TADP. The maximum and minimum levels for chlorine are 1.5 lb/TADP and a trace, and for chlorine dioxide are 0.78 lb/TADP and a trace.

5.1.11 Miscellaneous. Many mills report TRS emissions from miscellaneous sources such as black liquor storage tanks, tall oil plants, caustic plants and condensate stripping. Included in this section are some combined sources where several sources are vented in one stack. The data are too small and scattered to draw any meaningful conclusions.

5.1.12 Summary. The emission data, as reported in the industry questionnaires, are incomplete and some data are from a few tests or even single tests. However, these data have been compiled and estimates used where data are missing to arrive at emissions from the industry. Total particulate emissions are estimated at 98 000 tons/yr or 21 lb/TADP. Of this total, recovery furnaces are responsible for an estimated 17 lb/TADP. Total TRS emissions are estimated at 52 000 tons/yr or 11 lb/TADP. Of this total, recovery furnaces are responsible for an estimated 9 lb/TADP. Total sulphur dioxide emissions are estimated at 22 000 tons/yr or 5 lb/TADP. Because of incomplete data from some parts of the process the reported emission data may be low.

5.2 Air Contaminant Emission Summary - Sulphite Mills

Sulphur dioxide emissions are reported from only a few mills and a number of these results are reported as estimates. Appendix B, Table 1.11 shows blow pit emissions from five mills with an average of 44 lb/TADP and a maximum of 139 lb/TADP. Most mills have minimal control of blow pit emissions (usually vomit stack showers). Commercial equipment is available to control emissions of sulphur dioxide to less than 10 lb/TADP (Appendix A, Table 1).

Acid plant absorption tower (or tail gas tower) losses of up to 20 lb/TADP are reported from 11 mills (Appendix B, Table 1.11). The average emission is 4.7 lb/TADP. For comparison, Appendix A, Table 1 indicates that control of emissions to less than 4.0 lb/TADP is attainable with commercial equipment.

6 REGULATIONS AND GUIDELINES

In Canada, the control of air pollution from stationary sources is usually the direct responsibility of the provinces.* However, in pursuing the objective of promoting a uniform approach to pollution control in Canada, the federal government is authorized under the Clean Air Act to develop and publish national emission guidelines. The purpose of the guidelines is to set out emission limitations which might be looked upon as national "baselines" and considered by provincial governments as minimum standards on which to base their regulations. Embodied in these guidelines is the departmental philosophy of "Containment at Source" through the use of the "Best Practicable Control Technology" (27, 28).

For the pulp and paper industry, air pollution control legislation, in the form of regulations, guidelines and objectives has been promulgated or is being developed by many regulatory agencies. A summary of the emission limits laid down by some of these agencies is shown in Appendix A, Tables 2, 3 and 4.

There is a similarity in the limits proposed, although variations in the method and extent of application exist. For example, for new mills or major modification to existing mills, British Columbia has set a particulate emission limit of 0.10 gr/dscf from recovery furnaces (RF) and lime kilns (LK) and 0.40 lb/TADP from smelt dissolving tanks (SDT). TRS emissions from RF are limited to 6.5 ppm and from all other sources to 0.45 lb/TADP (Appendix A, Table 2). The U.S. Environmental Protection Agency (EPA) regulates eight significant TRS emission sources from new or modified kraft mills. Six of these sources (RF, MEE, BLO, BS washers, digesters, condensate stripping) are limited to 5 ppm. LK are limited to 8 ppm and SDT to 0.0084 g/kg of BLS. Particulate emission limits for RF are 0.044 gr/dscf, LK 0.066 gr/dscf and SDT 0.10 g/kg of BLS (Appendix A, Table 4).

However, the British Columbia objectives are less stringent for existing mills, for all types of emissions, than the limits for existing mills in Washington and Florida. British Columbia does say that all mills must eventually reach the new mill control limits. In Sweden, however, the limits for existing mills are relaxed only for particulates from both sulphite and kraft mills, although greater variance in observing the limits is granted

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* Exceptions for stationary air pollution sources include the situations described in Sections 7 and 9-18 of the Clean Air Act.

to existing mills. Examples of increasingly restrictive limits for existing mills within specified time periods are shown in the Washington State regulations and, to some extent, implied in the British Columbia objectives.

6.1 National Guidelines

The guidelines are intended to be emission limits for all periods of operation except for start-up or shutdown conditions or periods of upset operations.

6.1.1 Kraft Mills - New Plants. The following guidelines are intended as requirements for new plants:

Particulates	- Recovery Furnace	2.5 kg/MTADP
	- Lime Kiln	0.5 kg/MTADP
	- Smelt Dissolving Tank	0.25 kg/MTADP
TRS	- Recovery Furnace	0.15 kg/MTADP
	- Digesters, MEE, Condensate Stripping	0.015 kg/MTADP
	- Lime Kiln, Smelt Dissolving Tank, Brown Stock Washers, black Liquor Oxidation	0.225 kg/MTADP

6.1.2 Sulphite Mills - New Plants. The following guidelines are intended as requirements for new plants:

Particulates - 2.5 kg/MTADP
Sulphur Dioxide -10 kg/MTADP

6.1.3 Steam and Power Boilers - New Plants. The following guidelines are intended as requirements for new plants:

Particulates	
Coal Fired	- 230 mg/m^3 (0.10 gr/dscf) corrected to 12% CO_2
Combination Fired	- 340 mg/m^3 (0.15 gr/dscf) corrected to 12% CO_2
Oil Fired	- 160 mg/m^3 (0.07 gr/dscf) corrected to 12% CO_2

7 ECONOMIC CONSIDERATIONS

In assessing the impact of emission control costs on the wood pulping industry only new plants are being considered. These costs can be determined fairly accurately. For example, for a new 1000 ton/day kraft pulping plant the equipment and installation costs specifically associated with air contaminant emission control will range between 3 and 6 million dollars, depending on the type of controls installed (30). This represents 1 to 2% of the capital cost of the new plant. Most of the emission control equipment used to meet the emission limits is basically the same as would normally be installed for the recovery of chemicals for economic reasons, except that the efficiencies are higher. While this leads to higher capital and operating costs and hence to lower return on investment, the economic gains are nevertheless still positive and would be the equivalent of up to 7 dollars for each ton of pulp produced.

The construction of a recovery system in a new sulphite pulping plant is normally associated with water pollution abatement. The installation of equipment associated with purely air contaminant emission control would represent a small addition to the overall system and a very small increase in the total cost of the system.

The emission control costs for existing plants are very difficult to estimate because of factors such as age of the plant, its location and its layout. Modifications to existing plants must be addressed and specified on an individual plant basis. Many plants will have to improve process systems as well as emission control systems to reduce emissions to satisfactory levels. Provincial and/or municipal emission control agencies will be able to assess the control requirements of individual plants.

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30. Costs developed by the Air Pollution Control Directorate for air contaminant control systems that will keep emissions to the limits specified in the guidelines.

GLOSSARY

Abbreviations (Identical in both the singular and plural forms.)

acfm	actual cubic feet/minute
ADP	Air Dry Pulp (10% H_2O)
B	Bark or hog fuel
BHC	Blow Heat Condenser
BL	Black Liquor
BLO	Black Liquor Oxidation
BLS	Black Liquor Solids
BP	Bleach Plant
BS	Brown Stock
BT	Blow Tank
C	Coal
CC	Contaminated Condensate
CE	Caustic Extraction
CHW	Contaminated Hot Water
Cond.	Condensate
DCE	Direct Contact Evaporator
dscf	dry standard cubic feet
dscm	dry standard cubic metre
ESP	Electrostatic Precipitator
g	gram
gr	grain
hp	horsepower
LK	Lime Kiln

M	Million
MEE	Multiple Effect Evaporator
MTADP	Metric Tonne Air Dry Pulp (1000 kg)
NCG	Non-Condensible Gas
NSSC	Neutral Sulphite Semi-Chemical
ppb	parts per billion
ppm	parts per million
RF	Recovery Furnace
RMP	Refiner Mechanical Pulp
SBL	Strong Black Liquor
Sc	Scrubber
SDT	Smelt Dissolving Tank
SSL	Spent Sulphite Liquor
TADP	Ton Air Dry Unbleached Pulp (2000 lb)
TMP	Thermomechanical Pulp
TRS	Total Reduced Sulphur (as S)
WBL	Weak Black Liquor
wg	water gauge
WL	White Liquor
WW	Weak Wash
ww	white water

Chemical Symbols

$CaCO_3$	calcium carbonate
CaO	calcium oxide
$Ca(OH)_2$	calcium hydroxide
ClO_2	chlorine dioxide
CO_2	carbon dioxide

NaOH	sodium hydroxide
Na_2S	sodium sulphide
Na_2SO_4	sodium sulphate
$Na_2S_2O_3$	sodium thiosulphate
RSH	methyl mercaptan

H_2S	hydrogen sulphide	RSR	dimethyl sulphide
H_2SO_3	sulphurous acid	RSSR	dimethyl disulphide
Na_2CO_3	sodium carbonate	SO_2	sulphur dioxide

Definitions

Black Liquor	Weak black liquor is liquor recovered from the pulp at the washers. After concentration it is called strong black liquor.
Green Liquor	Liquor made by dissolving smelt in water or weak wash.
NCG	Volatile gases emitted from several parts of the kraft pulping process. A major portion of these gases may be TRS.
NSSC	Neutral Sulphite Semi-Chemical. A pulping process that uses a buffered (pH 8-10) alkaline cooking chemical - sodium or ammonium sulphite buffered with hydroxide or carbonate - to produce high yield pulp from hardwoods.
Oxidation Efficiency	Percentage reduction of sodium sulphide in the black liquor that is oxidized by blowing air or oxygen through the liquor.
Recovery Furnace	Unit used to burn recovered cooking liquor to produce steam and to reprocess cooking chemical. Conventional recovery furnaces use a DCE to utilize the heat in the flue gas for the final stage of black liquor concentration. "Low Odour" recovery furnaces reduce TRS emissions by replacing the DCE with a forced circulation or air contact evaporator (see Figure 3).
Smelt	Molten chemicals from the recovery furnace - mostly sodium carbonate and sulphide.
Sulphidity	In white liquor the percentage of sodium sulphide to sodium sulphide plus sodium hydroxide where all compounds are expressed as sodium oxide.
TRS	These are hydrogen sulphide and the organic sulphides (mostly methyl mercaptan, dimethyl sulphide and dimethyl disulphide). They are generated by the reaction of sodium sulphide with some of the wood components and are expressed as sulphur.
Weak Wash	Recovered liquor from lime mud washing.
White Liquor	Causticized green liquor - this is the cooking liquor.

ACKNOWLEDGMENT

Acknowledgment is extended to the staff of the Combustion Sources Division of the Air Pollution Control Directorate for the preparation of the section on Steam and Power Boilers and to the members of the Guideline Development Task Force for Air Emissions from the Wood Pulping Industry for their technical assistance and comments and suggestions offered for the improvement of this document.

APPENDIX A

APPENDIX A

TABLE 1 PROCESS EMISSIONS AND CONTROL METHODS*

Emission Source	Reported Emission lb/TADP	Test Data Note Number	Control Method	Reference
KRAFT PULP MILLS				
TRS				
Recovery Furnace Conventional (with DCE)	<0.1	See note 1	Two stage BLO	11
"Low Odour" (no DCE)	<0.04	See note 2	Furnace Design	11
Digester Multiple Effect Evaporator	<0.03	See note 3	Incineration	29
Steam Condensate Stripping	<0.03	See note 4	Incineration	29
Brown Pulp Washers	<0.04	See note 5	Incineration	11
Black Liquor Oxidation	<0.01	See note 6	Incineration	
	<0.1	See note 6	No control	29
Lime Kiln	<0.05	See note 7	Process control	29
Smelt Dissolving Tank	<0.02	See note 8	Wet Scrubber	29
PARTICULATES				
Recovery Furnace	<3.0	See note 9	ESP	29
Lime Kiln	<1.0	See note 10	Wet Scrubber	29
Smelt Dissolving Tank	<0.3	See note 11	Wet Scrubber	29
SULPHITE PULP MILLS				
SULPHUR DIOXIDE				
SSL Combustion Units	<20.0		Wet Scrubber	5,26
Acid Preparation	<4.0	See note 12	Secondary Wet Scrubber	5,26
Digester Discharge	<10.0	See note 13	Wet Scrubber	5,26
PARTICULATES				
Recovery Furnace	<5.0	See note 14	Wet Scrubber and Demister	
ALL PULP MILLS				
PARTICULATES				
Hog Fuel Boilers	<0.2 gr/dscf		Dry Centrifugal Cleaners	5,26

*These data have been reported from specific components of several mills. The sum of these numbers may not represent the total achievable emissions from any one mill.

TEST DATA NOTES

Each 4-hour test referred to consists of from 13 to 17 individual samples taken and tested by the U.S. EPA.

1. Continuous measurement of the stack gases of a conventional recovery furnace with a coulometric titrator - 17 month average - 3 ppm. Confirmed by a test over six days with a coulometric titrator and a gas chromatography unit all daily averages <4 ppm.

2. Continuous measurement of the stack gases of a "low odour" recovery furnace with a coulometric titrator - 26 month average - 1 ppm. Confirmed by a test over seven days with a coulometric titrator and a gas chromatography unit-all daily averages <1 ppm.

3. Four 4-hour gas chromatography tests each gave average TRS emissions of <3 ppm on combined NCG from digester and MEE. Highest individual sample tested <10 ppm.

4. Since emissions from steam condensate stripping are similar to digester and MEE emissions, incineration of the NCG would be expected to give similar control. Air stripping of condensates is not common in Canada and would be more difficult to control because of the large volume. A possible control might be to incinerate in a power boiler or recovery furnace.

5. The recovery furnace tested in note 2 incinerates brown stock washer emissions in the furnace. Since the total furnace emissions, including the washers, are <1 ppm the washer emission cannot be greater than this level.

6. No mills are known to incinerate BLO emissions. A new mill could probably control these emissions by incineration (power boiler, recovery furnace or separate incinerator). Control for an existing mill could be very difficult, except perhaps in a separate incinerator.

7. Six 4-hour tests from each of three LK. First kiln average of six tests was 10 ppm (highest individual sample was 65 ppm). Second kiln average of six tests was 6 ppm (highest individual sample was 74 ppm). Third kiln average of six tests was <2 ppm (highest individual sample was 6 ppm). This kiln used sodium hydroxide in the scrubber shower for control. Thirteen months of continuous monitoring data from this kiln showed maximum monthly daily averages ranging from 0.6 to 10 ppm.

8. Three 4-hour tests were made on each of two SDT. One installation showed an average TRS emission of 0.016 lb/TADP (8 ppm) - highest individual sample was 0.034 lb/TADP. The other installation showed an average of 0.0079 lb/TADP (2 ppm) - highest individual sample was 0.015 lb/TADP. Tests on 15 SDT all showed TRS emissions less than 0.025 lb/TADP (7 ppm).

9. Unit 1 - 17 months of company data showed an average particulate emission of 2.6 lb/TADP. Confirmed by tests which gave an average of 1.6 lb/TADP - range 1.3 to 1.8 lb/TADP. Unit 2 - 6 tests gave an average emission of 1.6 lb/TADP - range 1.4 to

1.8 lb/TADP. Unit 3 - 7 months of state agency data showed an emission range of 0.14 lb/TADP to 2.6 lb/TADP. Confirmed by 5 tests which showed a range of 0.13 to 0.17 lb/TADP. Unit 4 - 2 months of data (7 tests) from the company gave a particulate emission range of 0.52 to 2.5 lb/TADP. Six tests confirmed with a range of 0.58 to 0.76 lb/TADP. Unit 5 - 3 tests showed an emission range of 4.4 to 6.1 lb/TADP.

Three of the recovery furnace units shown above had DCE - units 1, 4 and 5; the other two were "low - odour" units. The particulate emission tests were of approximately 3-hour duration by EPA method 5. The operating rates during testing ranged from 74% of design capacity (unit 3) to 16% overload (unit 4). Four units operated with continuous soot blowing. Unit 5 had non-continuous soot blowing of approximately three hours a shift or less. The testing of unit 5 was during soot blowing; therefore emissions were higher than normal.

10.

Lime Kiln	Number of Tests	Particulate Emission (lb/TADP)			Fuel
		Average	Minimum	Maximum	
1	3	0.8	0.5	1.2	Gas
2	3	1.0	0.9	1.1	Oil
2	2	0.4	0.3	0.5	Gas
2	?*	0.4	0.12	0.6	?
3**	3	2.0	1.9	2.1	Oil
3	3	0.22	0.17	0.28	Gas
3	11***	0.33	0.14	0.53	Gas
4	3	0.59	0.25	0.79	Oil
4	3	0.34	0.28	0.39	Gas

* Seven months of state agency data.
** Kiln has operating problems when oil is used; gas is normally used.
***Operator tests over 3 months.

11.

Smelt Dissolving Tank	Number of Tests	Average	Particulate Emission (lb/TADP) Minimum	Maximum
1	3	0.14	0.096	0.18
2	?	0.1	0.096	0.106
3	4	0.21	0.20	0.22
3	?*	0.20	0.08	0.48
4	4	0.27	0.16	0.43
4	?*	0.21	0.13	0.40

* Ten months of state agency data.

12. Well operated acid-making systems, particularly those using a soluble base, may achieve losses at this level without a secondary scrubber.

13. Few data are available from well operating systems, but control of sulphur dioxide emissions at a 95% efficiency level (5) is expected.

14. These data supplied to task force subcommittee.

APPENDIX A

TABLE 2 REGULATIONS AND GUIDELINES FOR AIR CONTAMINANTS EMITTED BY THE WOOD PULPING INDUSTRY

	British Columbia Objective Level*		Alberta Control Order	Washington State Regulations	Florida State Regulations		Sweden Guidelines	
	A	B			New Mills	Existing Mills	New Mills	Existing Mills
Kraft Pulp Mills Recovery Furnace TRS Compounds lb/TADP as Sulphur			0.5	0.5				
H_2S, (ppm)	6.5	26			1.0	17.5	10	10
TRS Compounds lb/TADP as Sulphur from all other sources.	0.45	0.7						
Particulates lb/TADP (gr/dscf)								
Recovery Furnace	(0.10)	(0.20)	4.0	4.0	3.0	3.0	(0.10)	(0.20)
Lime Kilns	(0.10)	(0.20)	1.0	1.0			(0.10)	(0.10)
Smelt Tanks	0.40	0.8	0.5	0.5				
Wood-Burning Power Boilers**	(0.10)	(0.20)	1.6-4.9				(0.20)	(0.20)
Sulphite Pulp Mills								
Particulates, gr/dscf	0.10						0.1	0.2
SO_2, lb/TADP	20						20	40

*Average values for 24-hour period.

**Corrected to 12% CO_2.

APPENDIX A

TABLE 3 AMBIENT AIR GUIDELINES AND REGULATIONS FOR CONTAMINANTS EMITTED INTO THE ATMOSPHERE

		Sulphur Dioxide				Particulates			Hydrogen Sulphide		
		30 min	1 hour	24 hours	1 year	30 min	24 hours	1 year	30 min	1 hour	24 hours
Canada - National Air Quality Objectives											
Maximum desirable	$\mu g/m^3$		450	150	30			60		1 (yearly)	
	ppm		0.17	0.06	0.01						
Maximum Tolerable	$\mu g/m^3$			800			400				
Maximum acceptable	$\mu g/m^3$		900	300	60		120	70		15	5
	ppm		0.34	0.11	0.02						
Ontario - Air Pollution Control Regulations											
Max. desirable ambient air quality criteria	$\mu g/m^3$		690	275	55		120	60		30	
	ppm		0.25	0.10	0.02					0.02	
Single source max.	$\mu g/m^3$	830				100			30		
Alberta - Regulations											
	$\mu g/m^3$	525	450	150	30		100	60	17	14	4
	ppm	0.19	0.17	0.06	0.01				0.012	0.010	0.003
U.S.A. - Standards											
Primary	$\mu g/m^3$			365	80		260	75			
	ppm			0.13	0.03						
Secondary	$\mu g/m^3$		1300	260	60		150	60			
	ppm		0.50	0.09	0.02						
Sweden - Guidelines											
	$\mu g/m^3$	720		290	140*						
	ppm	0.25		0.10	0.05*						

*one month

APPENDIX A

TABLE 4 KRAFT PULP MILLS

STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES (UNITED STATES ENVIRONMENTAL PROTECTION AGENCY)

PROMULGATED 23 FEBRUARY, 1978

Maximum Emissions	Particulate Matter gr/dscf (g/dscm)	Total Reduced Sulphur ppm
Recovery Furnaces [a] - Straight	0.044 (0.10)	5
- Cross Recovery	0.044 (0.10)	25
Lime Kilns [b] - when burning gas	0.066 (0.15)	8
- when burning oil	0.13 (0.30)	8
Smelt Dissolving Tanks	0.10[c]	0.0084[c]
Digester Systems		5[b]
Multiple Effect Evaporator Systems		5[b]
Brown Stock Washer Systems		5[b]
Black Liquor Oxidation Systems		5[b]
Condensate Stripper Systems		5[b]

[a] All emissions measured at 8% oxygen. Cross recovery furnaces are defined as systems burning at least 7% NSSC liquor having a green liquor sulphidity of at least 28%. Visible emission from recovery furnaces limited to 35% opacity.

[b] All emissions measured at 10% oxygen.

[c] Grams/kg of black liquor solids burned (dry weight).

APPENDIX A

TABLE 5 CANADIAN PULP PRODUCING PLANTS

Company Name	Plant Location	Process Used*	Approximate Designed Capacity - TADP/day	
			Chemical	Mechanical
Atlantic Region				
Newfoundland				
Bowaters Newfoundland Ltd.	Cornerbrook	Sul., Mech.	400	940
Labrador Linerboard Ltd.	Stephenville	Kr.	1000	-
Price (Nfld) Pulp & Paper Ltd.	Grand Falls	Sul., Mech.	250	600
Nova Scotia				
Masonite Canada Ltd.	Hubbards	Mech.	Board - 310 M ft^2/yr (1/8" basis)	
Bowater Mersey Paper Co. Ltd.	Liverpool	Sul., Mech.	130	400
Minas Basin Pulp & Power Co. Ltd.	Hantsport	Mech.	-	75
Nova Scotia Forest Industries Ltd.	Port Hawkesbury	Sul., Mech.	650	400
Scott Maritimes Pulp Ltd.	New Glasgow	Kr.	600	-
New Brunswick				
Acadia Pulp and Paper Ltd.	Nelson-Miramichi	Mech.	-	390
Consolidated-Bathurst Ltd.	Bathurst	Kr., NSSC	220	360(NSSC)
Fraser Companies	Atholville	Sul.	300	-
Fraser Companies	Edmundston	Sul., Mech	465	360
Irving Pulp & Paper Ltd.	Saint John	Kr.	600	-
Lake Utopia Paper Ltd.	St. George	NSSC	220	-
MacMillan Rothesay Ltd.	Saint John	Mech.	-	850
Miramichi Timber Resources Ltd.	Newcastle	Kr.	700	-

N.B. International Paper Co.	Dalhousie	Sul., Mech.	220	600
St.Anne-Nackawic Pulp & Paper Co. Ltd.	Nackawic	Kr.	800	-
Quebec Region				
Abitibi Paper Co. Ltd.	Beaupré	Sul., Mech.	110	360
Reed Papers Ltd.	Quebec	Sul., Mech.	470	685
John Breakey Ltd.	Breakeyville	Mech.	-	43
Building Products of Canada Ltd.	LaSalle	Mech.	-	120**
Building Products of Canada Ltd.	Pont Rouge	Mech.	-	170**
Canadian Gypsum Co. Ltd.	Joliette	Mech.	Paper-115 t/d, Board-160M ft^2/day (1/2" basis)	
Canadian Gypsum Co. Ltd.	Louiseville	Mech.	Board - 105 M ft^2/day	
Canadian International Paper Co.	Gatineau	Mech.	-	1215
Canadian International Paper Co.	Latuque	Kr.	1295	-
Canadian International Paper Co.	Matane	NSSC	200	-
Canadian International Paper Co.	Trois Rivières	Sul., Mech.	260	750
Canadian Johns-Manville Co. Ltd.	Asbestos	Mech.	-	60**
Consolidated-Bathurst Ltd.	Grand'Mère	Sul., Mech.	175	550
Consolidated-Bathurst Ltd.	New Richmond	Kr.	650	-
Consolidated-Bathurst Ltd.	Port Alfred	Sul., Mech.	215	665
Consolidated-Bathurst Ltd.	Portage du Fort	Kr.	580	-
Consolidated-Bathurst Ltd.	Shawinigan	Sul., Mech.	250	780
Consolidated-Bathurst Ltd.(Island Mill)	Trois Rivières	Kr., Mech.	285	260
Consolidated-Bathurst Ltd.(Cape Mill)	Trois Rivières	Mech.	-	300
Domtar Newsprint Ltd.	Dolbeau	Sul., Mech.	180	375
Domtar Newsprint Ltd.	Donnacona	Sul., Mech.	220	400
Domtar Fine Papers Ltd.	Windsor	Kr.	475	-

Domtar Packaging Ltd.	East Angus	Kr., NSSC	220	120(NSSC)
Domtar Pulp Ltd.	Lebel-sur-Quévillon	Kr.	750	-
The Donohue Co. Ltd.	Clermont	Sul., Mech.	150	615
The E.B. Eddy Co.	Hull	Mech.	-	175
Gaspesia Pulp & Paper Co. Ltd.	Chandler	Sul., Mech.	190	495
Kruger Pulp & Paper Ltd.	Bromptonville	Mech.	-	505
The James McLaren Co. Ltd.	Buckingham	Sul., Mech.	130	350
Masonite (Canada) Ltd.	Gatineau	Mech. (Fiberboard)	135M ft^2/yr (1 1/2" basis)	
Masonite (Canada) Ltd.	Gatineau	Mech. (Hardboard)	230M ft^2/yr (1/8" basis)	
Megantic Manufacturing Co. Ltd.	Lake Megantic	Mech.	Board - 12M ft^2/yr (1/2" basis)	
Mohawk Pulp Co. Ltd.	Rivière-du-Loup	Mech.	-	40
The Price Co. Ltd.	Alma	Sul., Mech.	250	800
The Price Co. Ltd.	Kenogami	Kr., Mech.	240	60
		Sul., Mech.	275	560
Quebec North Shore Paper Co.	Baie Comeau	Sul., Mech.	425	1400
Rayonier Quebec Ltd.	Port Cartier	Sul.	750	-
St. Raymond Paper Ltd.	Desbiens	Sul.	135	-
St. Raymond Paper Ltd.	St. Raymond	Mech.	-	64
Scott Paper Ltd.	Crabtree	Mech.	-	40
F.F. Soucy Inc.	Rivière-du-Loup	Mech.	-	470
Tembec Forest Products Inc.	Temiscaming	Sul.	470	-
Three Rivers Pulp & Paper Co. Ltd.	Trois Rivières	Sul., Mech.	230	700
Thurso Pulp & Paper Co.	Thurso	Kr.	325	-
Ontario Region				
Abitibi Paper Co. Ltd. (Thunder Bay Division)	Thunder Bay	Sul., Mech.	120	360
Abitibi Panel Products Ltd.	Sturgeon Falls	NSSC	220	-

Abitibi Paper Co. Ltd.	Iroquois Falls	Sul., Mech.	240	710
Abitibi Paper Co. Ltd.	Sault Ste Marie	Mech.	-	300
Abitibi Paper Co. Ltd.	Smooth Rock Falls	Kr.	375	-
Abitibi Paper Co. Ltd. (Fort William Division)	Thunder Bay	Sul., Mech.	90	260
Abitibi Provincial Paper Ltd.	Thunder Bay	Sul., Mech.	100	300
American Can of Canada Ltd.	Marathon	Kr.	500	-
The Beaver Wood Fiber Co. Ltd.	Thorold	Mech.	-	125
Canadian International Paper Co.	Hawkesbury	Sul.	277	-
Canadian Johns-Manville Co. Ltd.	North Bay	Mech.	-	120**
Domtar Fine Papers Ltd.	Cornwall	Kr.	400	-
Domtar Packaging Ltd.	Red Rock	Kr., Mech.	750	200
Domtar Packaging Ltd.	Trenton	NSSC	150	-
Reed Paper Co. Ltd.	Dryden	Kr.	630	-
Eddy Forest Products Ltd.	Espanola	Kr.	720	-
The Great Lakes Paper Co. Ltd.	Thunder Bay	Kr., Mech.	1250	1000
		Sul.	300	-
Kimberly-Clark of Canada Ltd.	Terrace Bay	Kr.	450	-
The Ont.-Minnesota Pulp & Paper Co. Ltd.	Fort Francis	Kr., Mech.	520	525
The Ont.-Minnesota Pulp & Paper Co. Ltd	Kenora	Sul., Mech.	220	540
The Ontario Paper Co. Ltd.	Thorold	Sul., Mech.	245	540
Spruce Falls Power & Paper Co. Ltd.	Kapuskasing	Sul., Mech.	620	940

Northwest Region

Manitoba

Abitibi Manitoba Paper Ltd.	Pine Falls	Sul., Mech.	130	380

Building Products of Canada Ltd.	Winnipeg	Mech.	-	70**
Manitoba Forestry Resources Ltd.	The Pas	Kr.	400	-
Saskatchewan				
Domtar Construction Materials Ltd.	Saskatoon	Mech.	-	35
Prince Albert Pulp Co. Ltd.	Prince Albert	Kr.	850	-
Alberta				
Building Products of Canada Ltd.	Edmonton	Mech.	-	135**
Building Products of Canada Ltd.	Wabamum	Mech.	-	
IKO Industries Ltd.	Calgary	Mech.		60**
North Western Pulp & Power Ltd.	Hinton	Kr.	550	-
Proctor & Gamble Cellulose Ltd.	Grande Prairie	Kr.	750	-
Pacific Region				
British Columbia Forest Products Ltd.	Crofton	Kr., Mech.	1150	560
British Columbia Forest Products Ltd.	MacKenzie	Kr.	580	-
Canadian Cellulose Co. Ltd.	Castlegar	Kr.	600	-
Canadian Cellulose Co. Ltd.	Prince Rupert	Kr.	800	
Canadian Forest Products Ltd.	New Westminster	Mech.	-	180**
Canadian Forest Products Ltd.	Port Mellon	Kr.	800	-
Cariboo Pulp & Paper Co. Ltd.	Quesnel	Kr.	905	-
Crestbrook Pulp & Paper Ltd.	Skookumchuck	Kr.	400	-
Crown Zellerbach Canada Ltd.	Campbell River	Kr., Mech.	1200	550
Eurocan Pulp & Paper Co. Ltd.	Kitimat	Kr.	915	-
Finlay Forest Industries Ltd.	Mackenzie	Mech.	-	300
Intercontinental Pulp Co. Ltd.	Prince George	Kr.	700	-
MacMillan Bloedel Ltd.	Nanaimo	Kr.	1250	-
MacMillan Bloedel Ltd.	Port Alberni	Kr., Mech.	795	805

MacMillan Bloedel Ltd.	Powell River	Kr., Mech.	550	1340
Northwood Pulp & Timber Ltd.	Prince George	Kr.	800	-
Ocean Falls Corporation	Ocean Falls	Mech.	-	275
Prince George Pulp & Paper Ltd.	Prince George	Kr.	800	-
Rayonier (Canada) Ltd.	Port Alice	Sul.	450	-
Rayonier (Canada) Ltd.	Woodfibre	Kr.	600	-
Scott Paper Ltd.	New Westminster	Mech.	-	70
Tahsis Co. Ltd.	Gold River	Kr.	750	-
Weyerhaeuser Canada Ltd.	Kamloops	Kr.	1250	-

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* Kr. - Kraft, Sul. - Sulphite, Mech. - Mechanical, NSSC - Neutral Sulphite Semi-Chemical.

**Total plant production - not necessarily all plant produced pulp.

APPENDIX A

TABLE 6 PRINCIPAL LOGGING STATISTICS - 1973

A - PULPWOOD LOGGING

Province	Establishments	Production and related workers	Production and related workers Wages	Working Owners and Partners	Total Employees	Total Employees Salaries & Wages	Value Added
	Number	Number	$'000	Number	Number	$'000	$'000
Newfoundland	28	2 151	17 738	21	2 399	20 343	29 242
Nova Scotia	164	1 160	6 128	149	1 251	7 104	12 671
New Brunswick	217	2 888	22 704	163	3 395	26 825	47 354
Quebec	169	9 995	93 219	74	11 845	111 589	170 259
Ontario	236	6 244	71 909	153	7 340	84 330	122 013
Canada	886	23 788	225 418	618	27 889	266 780	408 327

Figures for the other provinces and for the territories are either nil (Prince Edward Island, Yukon and Northwest Territories) or confidential to meet secrecy requirements of the Statistics Act. (Manitoba, Saskatchewan, Alberta.)

For British Columbia see notes to table.

Source: Statistics Canada - Logging 1973, Catalogue No. 25-201 annual.

APPENDIX A

TABLE 6 (Cont.) PRINCIPAL LOGGING STATISTICS - 1973

B - TOTAL LOGGING

Province	Establishments	Production and related workers		Working Owners and Partners	Total Employees		Value Added
			Wages			Salaries & Wages	
	Number	Number	$'000	Number	Number	$'000	$'000
Newfoundland	32	2 156	17 764	23	2 404	20 369	29 293
Nova Scotia	215	1 416	7 379	189	1 524	8 457	14 991
New Brunswick	273	3 967	30 721	197	4 533	35 332	60 763
Quebec	335	12 667	115 773	144	14 690	135 695	210 848
Ontario	400	7 677	84 257	257	8 983	98 699	145 762
Manitoba, Saskatchewan, Alberta	211	2 137	20 263	181	2 546	24 134	41 243
British Columbia:							
Coast	648	11 998	153 518	160	14 291	186 592	433 904
Interior	1 018	7 555	83 048	547	8 615	96 491	172 360
Canada	3 132	49 573	512 724	1 698	57 586	605 769	1 109 162

Figures for the other provinces and for the territories are nil (Prince Edward Island, Yukon and Northwest Territories).

Source: Statistics Canada - Logging 1973, Catalogue No. 25-201 annual.

APPENDIX A TABLE 6 (Cont.) NOTES
ECONOMIC IMPACT OF THE PULPWOOD INDUSTRY
THE PULPWOOD LOGGING (S.I.C. 0311)

This industry resulted from the sub-division of the industry "Logging", S.I.C. 0311. As its name implies, it includes establishments primarily engaged in pulpwood operations. Beginning with 1970, separate industry statistics for pulpwood logging were compiled. British Columbia has no establishments coded to this industry. This is due to many integrated operations in reporting production and deliveries do not distinguish between sawlogs, veneer logs and pulpwood.

1) The number of employees are reported in the form of annual averages and represent as closely as possible full time employment; adjustments are made when reported figures indicate the existence of part time or seasonal employment.
2) Production and related workers. In addition to those engaged in production, they include employees engaged in maintenance, repair, janitorial, cooking and watchman services and working foremen engaged in similar work to that of the employees they supervise.
3) Working Owners and Partners. These are not included in the statistics of employees and salaries and wages. There is some duplication in numbers when a person owns more than one establishment and is reported as a working owner on each Census return.

APPENDIX B

APPENDIX B

TABLE 1 AIR CONTAMINANT EMISSION SUMMARY*

Kraft Mills	Particulate	TRS	SO_2
Table 1.1	Recovery Furnaces		
Number of mills reporting	39	31	21
Average emission, lb/TADP	17.3	7.87	4.2
Median emission, lb/TADP	9.0	2.7	2.4
Maximum emission, lb/TADP	108	41.4	25.6
Minimum emissions, lb/TADP	0.7	0.014	0.2
Table 1.2	Smelt Dissolving Tanks		
Number of mills reporting	28	24	1
Average emission, lb/TADP	1.96	0.08	0.3
Median emission, lb/TADP	1.2	0.06	
Maximum emission, lb/TADP	8.3	0.5	
Minimum emission, lb/TADP	0.04	0.004	
Table 1.3	Causticizers		
Number of mills reporting	4	6	
Average emission, lb/TADP	0.5	0.002	
Maximum emission, lb/TADP	1.5	0.007	
Minimum emission, lb/TADP	0.009	0.0001	
Table 1.4	Lime Kilns		
Number of mills reporting	35	26	12
Average emission, lb/TADP	1.45	0.24	0.51
Median emission, lb/TADP	0.89	0.18	0.17
Maximum emission, lb/TADP	12.7	3.07	4
Minimum emission, lb/TADP	0.08	0.002	0.01

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* Excluding estimated data. However, estimated data are generally similar to reported data.

	TRS
Table 1.5	Digesters*
Number of mills reporting	5
Average emission, lb/TADP	1.76
Median emission, lb/TADP	0.86
Maximum emission, lb/TADP	4.5
Minimum emission, lb/TADP	0.24
Table 1.6	Knotters and Washers*
Number of mills reporting	18
Average emission, lb/TADP	0.19
Median emission, lb/TADP	0.13
Maximum emission, lb/TADP	0.78
Minimum emission, lb/TADP	0.02
Table 1.7	Black Liquor Oxidation**
Number of mills reporting	9
Average emission, lb/TADP	0.15
Median emission, lb/TADP	0.10
Maximum emission, lb/TADP	0.56
Minimum emission, lb/TADP	0.03
Table 1.8	Multiple Effect Evaporators*
Number of mills reporting	10
Average emission, lb/TADP	0.89
Median emission, lb/TADP	0.63
Maximum emission, lb/TADP	2.4
Minimum emission, lb/TADP	0.06

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* Reported data from mills with no emission control. For data from all mills see Appendix B, Table 1.12.

** Reported data from mills with BLO systems only. For all mills see Appendix B, Table 1.12.

	Cl_2	ClO_2
Table 1.9	Total Bleach Plant	
Number of mills reporting	6	6
Average emission, lb/TADP	1.0	0.29
Maximum emission, lb/TADP	4.8	0.5
Minimum emission, lb/TADP	0.01	0.0005
Table 1.10	Chlorine Dioxide Generators	
Number of mills reporting	4	4
Average emission, lb/TADP	0.4	0.25
Maximum emission, lb/TADP	1.5	0.78
Minimum emission, lb/TADP	Trace	Trace

Sulphite Mills (SO_2)

Table 1.11	Blow Pits	Acid Plants
Number of sources reported	5	11
Average emission, lb/TADP	44	4.7
Median emission, lb/TADP		2
Maximum emission, lb/TADP	139	20
Minimum emission, lb/TADP	1.4	0.025

Table 1.12

Emission Calculations

Kraft Mills

1974 Production - 9 348 000 TADP (Ref. 6)

- From questionnaires total daily production adds up to 30 095 TADP. Apparent operating days = 310.62

Particulates

Recovery Furnace 9 348 000 x 17.19*/2000 = 80 350

Smelt Dissolving Tank 9 348 000 x 2.00*/2000 = 9 360

Lime Kiln 9 088 741** x 1.75*/2000 = 7 930

Total 97 640 t/yr

Sulphur Dioxide

Recovery Furnace 9 348 000 x 4.17***/2000 = 19 510

Lime Kiln 9 088 741 x 0.51***/2000 = 2 320

Total 21 830 t/yr

Total Reduced Sulphur (TRS)

Assume - 1. Incineration 100% efficient in controlling TRS.
2. Scrubbing, etc. 80% efficient in controlling TRS.

Recovery Furnace - 9 348 000 x 8.80*/2000 = 41 140 t/yr

Smelt Dissolving Tank - 9 348 000 x 0.083***/2000 = 390 t/yr

Lime Kiln - 9 088 741 x 0.24***/2000 = 1 090 t/yr

Digester

Incineration - 6256 x 310.62 x 0 = 0

Scrubbing, etc. - 6359 x 310.62 x 1.75 x 0.20/2000 = 350

No control - 17 480 x 310.62 x 1.75***/2000 = 4 760

Digester Total - t/yr 5 110

Average - 5112 x 2000/9 348 000 = 1.09 lb/TADP

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* Average - including guesstimates from sources with no data.

** Production for 1974 less three mills with no LK.

*** Sources with no data assumed to have the same average emissions as reported sources.

Knotters and Washers

Incineration - 750 x 310.62 x 0 = 0

Scrubbing, etc. - 1912 x 310.62 x 0.19 x 0.20/2000 = 10

No Control - 27 433 x 310.62 x 0.19*/2000 = 810

Knotter and Washer Total - t/yr 820

Average - 820 x 2000/9 348 000 = 0.18 lb/TADP

Black Liquor Oxidation

No black liquor oxidation - 15 610 x 310.62 x 0 = 0

No control - 14 761 x 310.62 x 0.15/2000 = 340

BLO Total - t/yr 340

Average - 340 x 2000/9 348 000 = 0.07 lb/TADP

Multiple Effect Evaporators

Incineration - 5731 x 310.62 x 0 = 0

Scrubbing, etc. - 2060 x 310.62 x 0.89 x 0.20/2000 = 60

No control - 22 304 x 310.62 x 0.89/2000 = 3080

MEE Total - t/yr 3140

Average - 3140 x 2000/9 348 000 = 0.67 lb/TADP

Miscellaneous

Insufficient data to calculate emissions

Total TRS - t/yr 52 030

Sulphite Mills

The questionnaire data were considered insufficient for emission calculations. A national inventory estimate for sulphur dioxide emissions is shown in Section 3.

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*Sources with no data assumed to have the same average emissions as reported sources.

APPENDIX C

APPENDIX C : TABLE 1 PULP AND PAPER INDUSTRY ENERGY DISTRIBUTION BY REGIONS

EPS REGION \ FUEL	COAL		OIL		GAS *		WOOD WASTE		TOTAL
	10^9Btu/yr	%	10^9Btu/yr	%	10^9Btu/yr	%	10^9Btu/yr	%	10^9Btu/yr
ATLANTIC	0	0	53 200	93	700*	1	3 600	6	57 500
QUEBEC	4 900	7	51 800	77	800	1	11 000	15	68 500
ONTARIO	7 000	14	9 200	19	26 000	53	7 200	14	49 400
NORTHWEST	3 300	24	2 100	15	5 500	39	3 100	22	14 000
PACIFIC	0	0	32 100	40	13 200	16	35 000	44	80 300
TOTAL	15 200	-	148 400	-	46 200	-	59 900	-	269 700

ASSUMING: COAL=13 000 Btu/lb
OIL=180 000 Btu/gal
GAS = 1 000 Btu/cu. ft
WOOD WASTE = 8 000 Btu/lb (dry)
LPG = 103 000 Btu/gal

% = Percent of energy supplied by given fuel within region
* = Includes LPG

APPENDIX C: TABLE 2 PULP AND PAPER INDUSTRY TOTAL FUEL CONSUMPTION - ANNUAL

EPS REGION \ FUEL	COAL (tons)	OIL (bbls)	GAS (Mcf)	WOOD WASTE (dryton)
ATLANTIC	0	8 447 000	7.1*	224 000
QUEBEC	189 770	8 228 000	848	688 000
ONTARIO	269 211	1 466 000	26 000	450 000
NORTHWEST	128 000	339 000	5 500	191 000
PACIFIC	0	5 092 000	13 200	2 218 000

*1 Mill only - M Imp. Gal (LPG)

APPENDIX C : TABLE 3 PULP AND PAPER INDUSTRY NO. OF MILLS IN EACH REGION USING GIVEN FUEL COMBINATIONS

FUELS / EPS REGION	COAL WOOD WASTE	OIL WOOD WASTE	GAS WOOD WASTE	COAL OIL WOOD WASTE	COAL GAS WOOD WASTE	OIL GAS WOOD WASTE	COAL OIL GAS WOOD WASTE	COAL	OIL	GAS	COAL OIL	COAL GAS	OIL GAS	COAL OIL GAS	% OF MILLS USING 2 OR MORE FUELS
ATLANTIC *18		12							6						70
QUEBEC **38/40	1	17		2				1	12		2		2		70
ONTARIO 23		3		1	10	2				2			3	2	90
NORTHWEST 10	1	1	1			2				4			1		60
PACIFIC 21		10	4			6				1					95

* *total mills in region*

** data for 38 of 40 mills

APPENDIX C: TABLE 4 PULP AND PAPER INDUSTRY NO. OF MILLS AND BOILERS USING MIXED FIRING*

EPS REGION	1 TOTAL NO. OF MILLS IN REGION	2 NO. OF MILLS USING MIXED FIRING	3 TOTAL NO. OF UNITS IN 2	4 TOTAL NO. OF MIXED FIRED UNITS IN 3	5 % MIXED FIRED UNITS IN 3
ATLANTIC	18	12	30	15	50
QUEBEC	38 **40	20	76	23	30
ONTARIO	23	16	58	25	43
NORTHWEST	10	4	8	6	75
PACIFIC	21	20	49	37	75

* Mixed Firing = Wood Waste + Any combination of Fossil Fuel

** *total mills = 40, data for 38 mills*

APPENDIX C: TABLE 5 PULP AND PAPER INDUSTRY NO. OF MILLS WITH GIVEN NO. OF BOILERS

NO. OF BOILERS PER MILL / EPS REGION	1	2	3	4	5	≥ 6
ATLANTIC *18	5	2	7	1	2	1
QUEBEC **38/40	4	8	8	5	7	5
ONTARIO 23	0	5	10	3	3	2
NORTHWEST 10	3	5	1	1	0	0
PACIFIC 21	7	4	4	5	1	0

* total mills in region
** data for 38 of 40 mills

APPENDIX C: TABLE 6 PULP AND PAPER INDUSTRY BOILER SIZE DISTRIBUTION NO. OF BOILERS IN GIVEN DESIGN SIZE RANGE

SIZE (lb stm/hr) / EPS REGION	0-49 999	50 000-99 999	100 000-199 999	200 000-299 999	300 000-399 999	400 000-499 999	> 500 000 -
ATLANTIC *44/50	4	7	19	9	2	0	3
QUEBEC	31	37	38	11	5	1	3
ONTARIO 75/81	16	14	35	6	1	2	1
NORTHWEST 20/20	9	3	2	3	1	1	1
PACIFIC 44/53	1	7	16	5	4	6	5

* data for 44 of 50 boilers

APPENDIX C: TABLE 7 PULP AND PAPER INDUSTRY
FUEL SULPHUR DISTRIBUTION
- OIL (No. of Mills and Total Annual Consumption per Region)

FUEL ANALYSIS / EPS REGION	0.5-0.9%S		1.0-1.4%S		1.5-1.9 %S		2.0-2.4 %S		2.5-3.0 %S		3.0 %S	
	No. of Mills	Total Bbls	No. of Mills	Total Bbls	No. of Mills	Total Bbls	No. of Mills	Total Bbls	No. of Mills	Total Bbls	No. of Mills	Total Bbls
ATLANTIC *Mills =17/18 **Vol=14/18					1	450 000	8	3 183 000	8	4 813 000		
QUEBEC Mills=35/36 Vol.=30/36					2	50 000 1/2	11	1 620 000 9/11	22	6 560 000 20/22		
ONTARIO Mills=11/11 Vol.=11/11	2	45 000			1	10 000	6	1 079 000	2	332 000		
NORTHWEST Mills=3/4 Vol.=3/4	1	24 000			1	310 000	1	nil				
PACIFIC Mills =14/16 Vol.=14/16	4	1 726 000	3	820 000	7	2 395 000						

*fuel analysis for 17 of 18 mills
** fuel consumption data for 14 of 18 mills

APPENDIX C: TABLE 8 PULP AND PAPER INDUSTRY
FUEL SULPHUR DISTRIBUTION
- COAL (No. of Mills and Total Annual Consumption per Region

FUEL ANALYSIS / EPS REGION	0.5-0.9%S		1.0-1.4%S		1.5-1.9 %S		2.0-2.4 %S		2.5-3.0 %S		3.0 %S	
	No. of Mills	tons/yr	No. of Mills	tons/yr	No. of Mills	tons/yr	No. of Mills	tons/yr	No. of Mills	tons/yr	No. of Mills	tons/yr
ATLANTIC		-		-	-	-		-		-		-
QUEBEC **Mills 5/5 ***Fuel 5/5	2*	22 000							1	1 770	2	166 000
ONTARIO Mills 12/13 Vol. 12/13	5	71 000	3	36 000	1	44 000	1	16 000	1	80 000	1	22 000
NORTHWEST Mills 1/1 Fuel 1/1	1	128 000										
PACIFIC		-		-		-		-		-		-

* No sulphur content given
** Fuel analysis available for 5 of 5 mills
*** Fuel consumption for 5 of 5 mills

APPENDIX C: TABLE 9 PULP AND PAPER INDUSTRY
ANNUAL FUEL CONSUMPTION DISTRIBUTION - No. of Mills in each Category

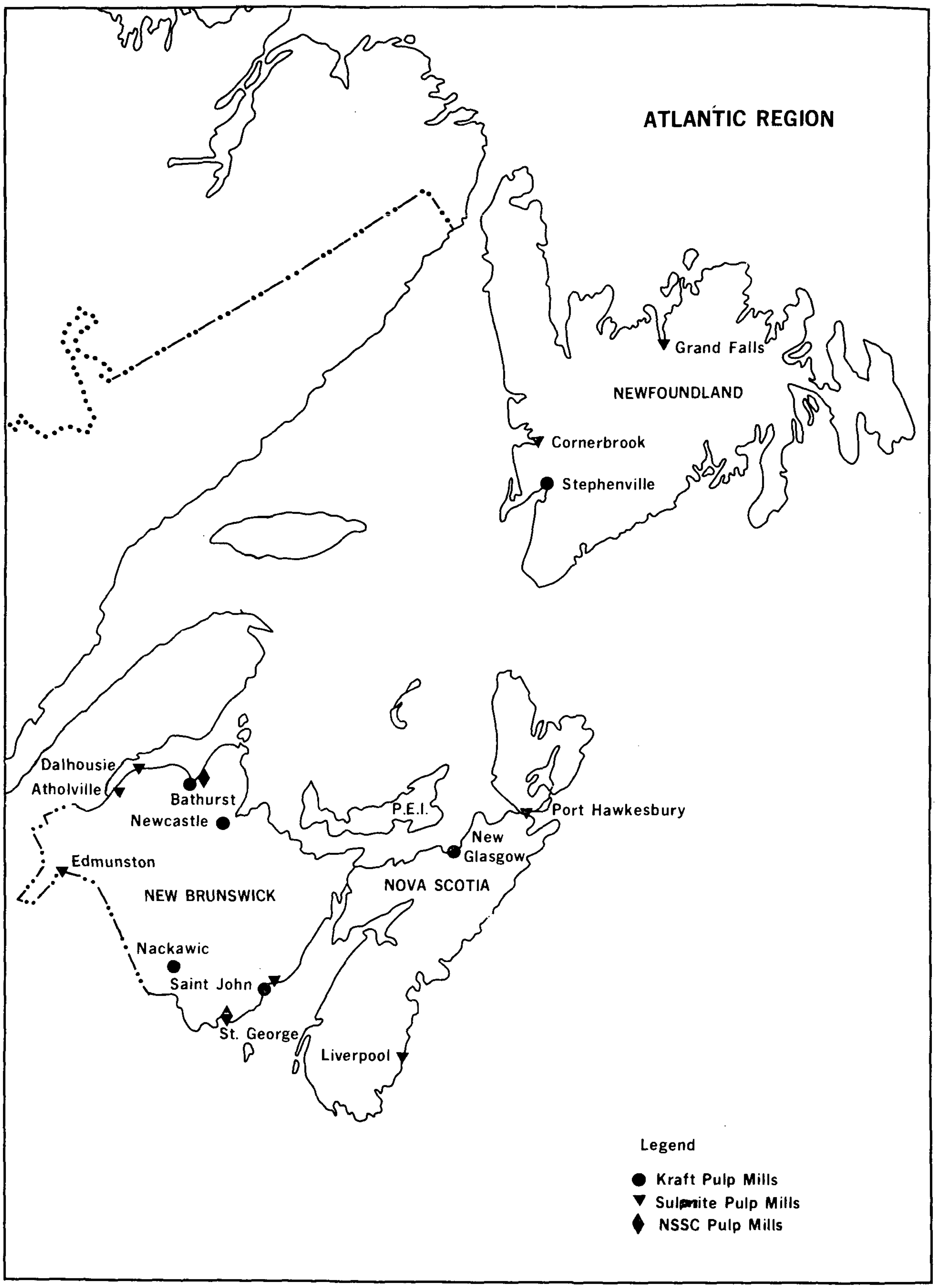
FUEL CONSUMPTION / EPS REGION	COAL			OIL				GAS			
	0-25M tons/yr	26-50M tons/yr	> 50M tons/yr	0-200M Bbls	201-400M Bbls	401-600M Bbls	>600M Bbls	0-1000 Mcf	1001-2000 Mcf	2001-4000 Mcf	4001-8000 Mcf
ATLANTIC O=15 18 G=1/2				3	2	7	3	1			
QUEBEC C=5/5 O=30/36	3	1	1	15	9	3	3				
ONTARIO C=12 13· O=11 11·· G-17 19···	8	3	1	7	4			7	6	3	1
NORTHWEST C=1 1 O=4 4 G=5 7			1	2	2			4			1
PACIFIC O=16 16 G=11/11				7	2	4	3	7	3		1

· coal consumption data available for 12 of 13 mills

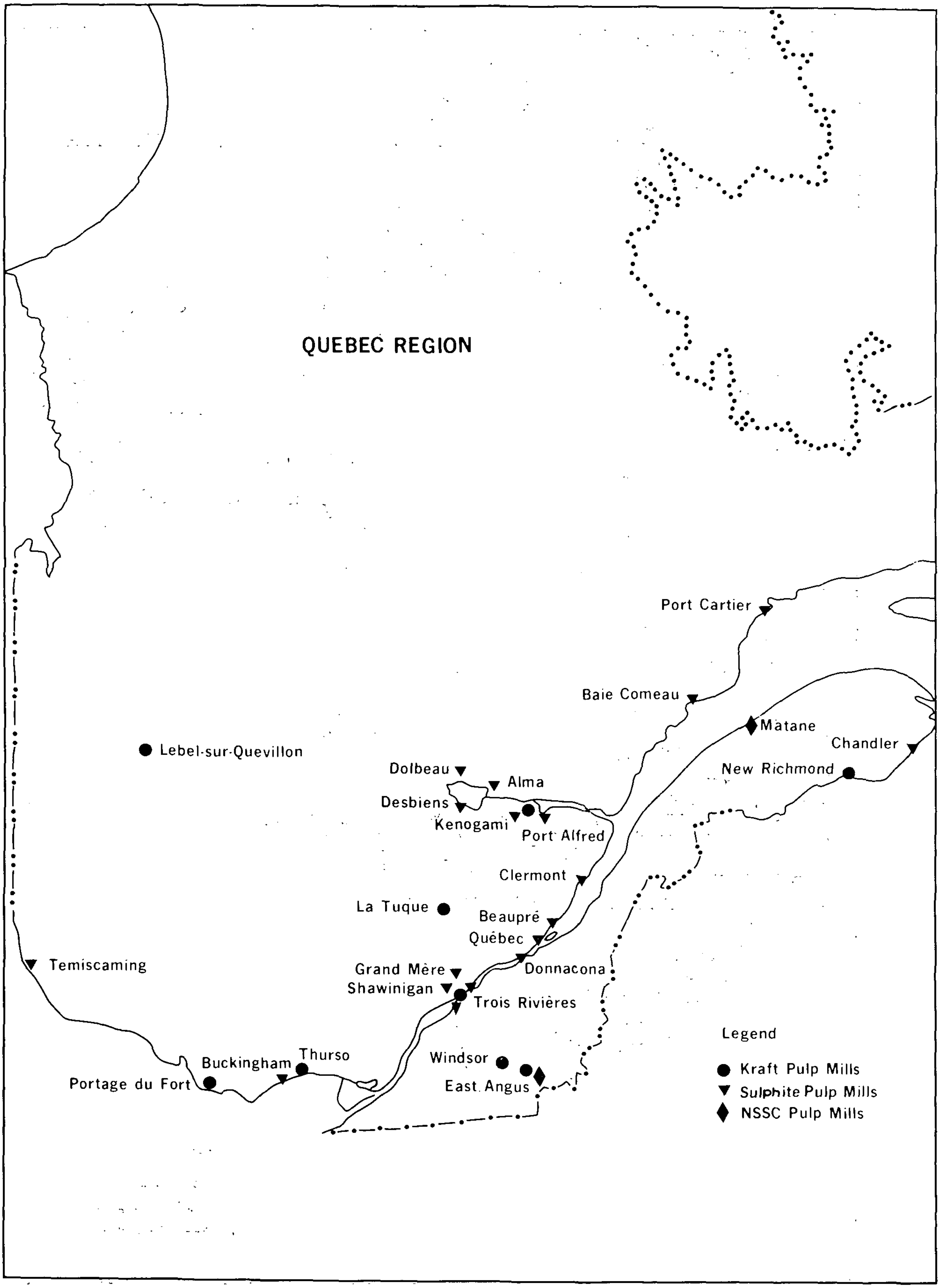
·· oil consumption data available for 11 of 11 mills

··· gas consumption data available for 17 of 19 mills

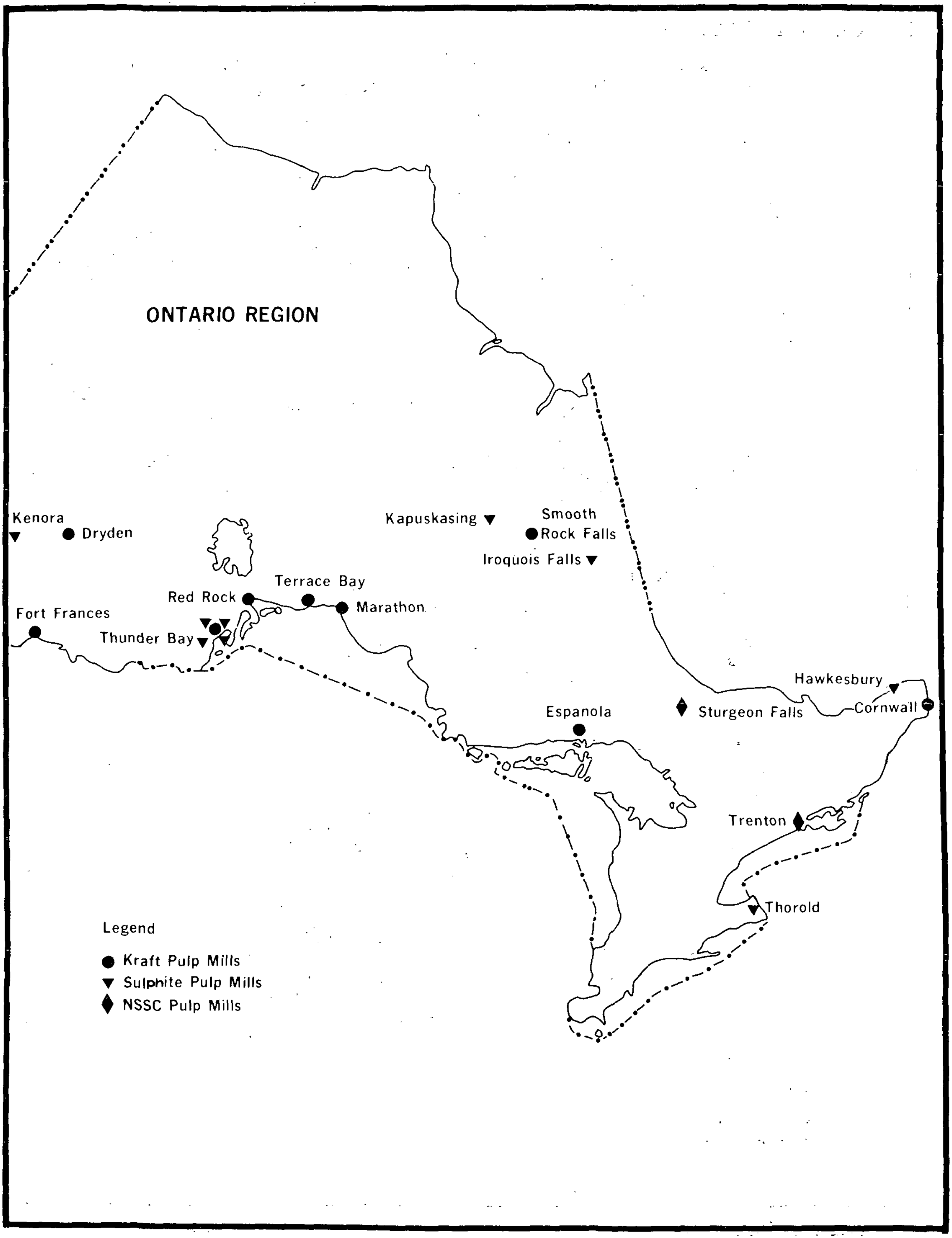
APPENDIX D



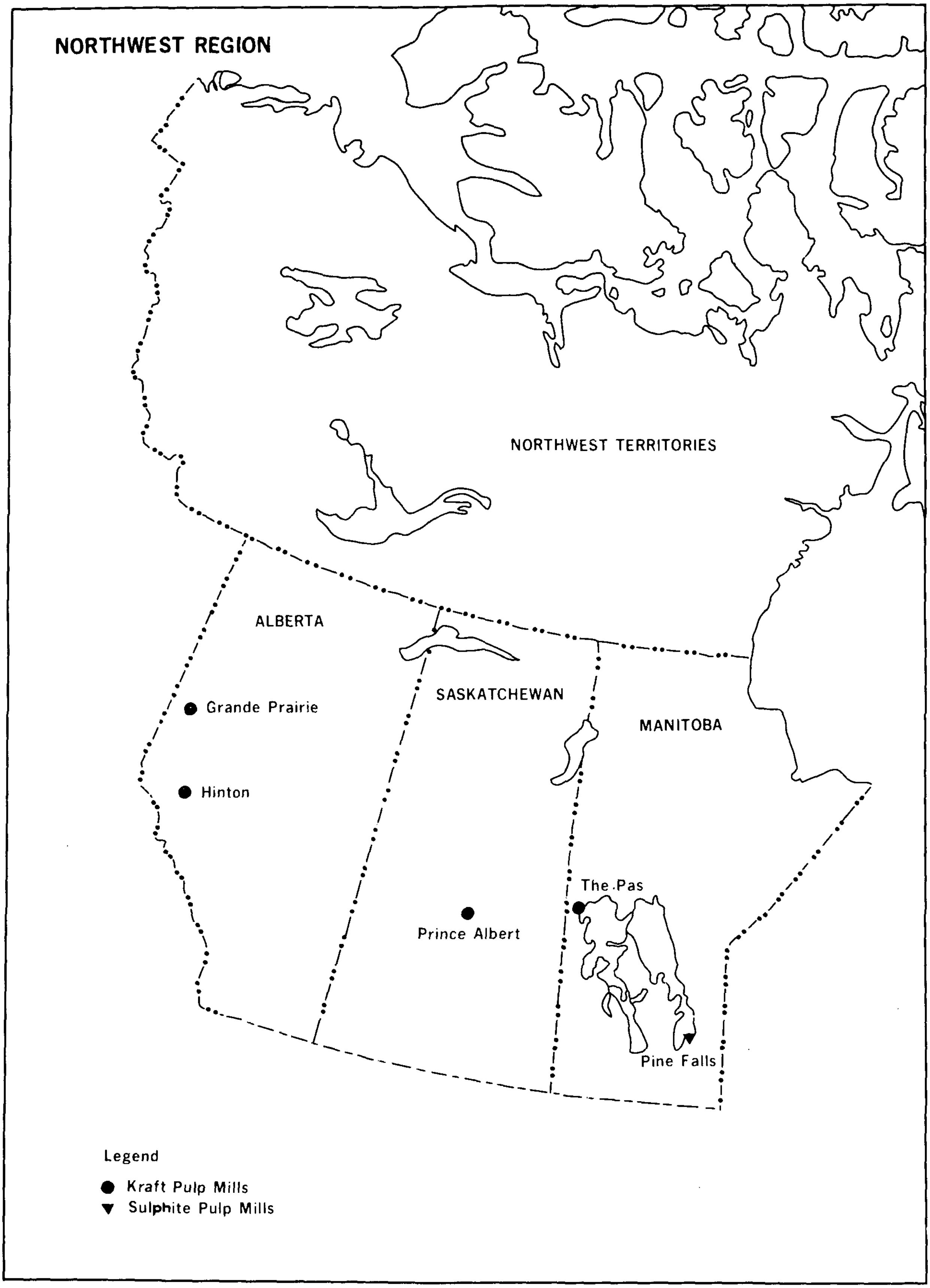
APPENDIX D: FIGURE 1



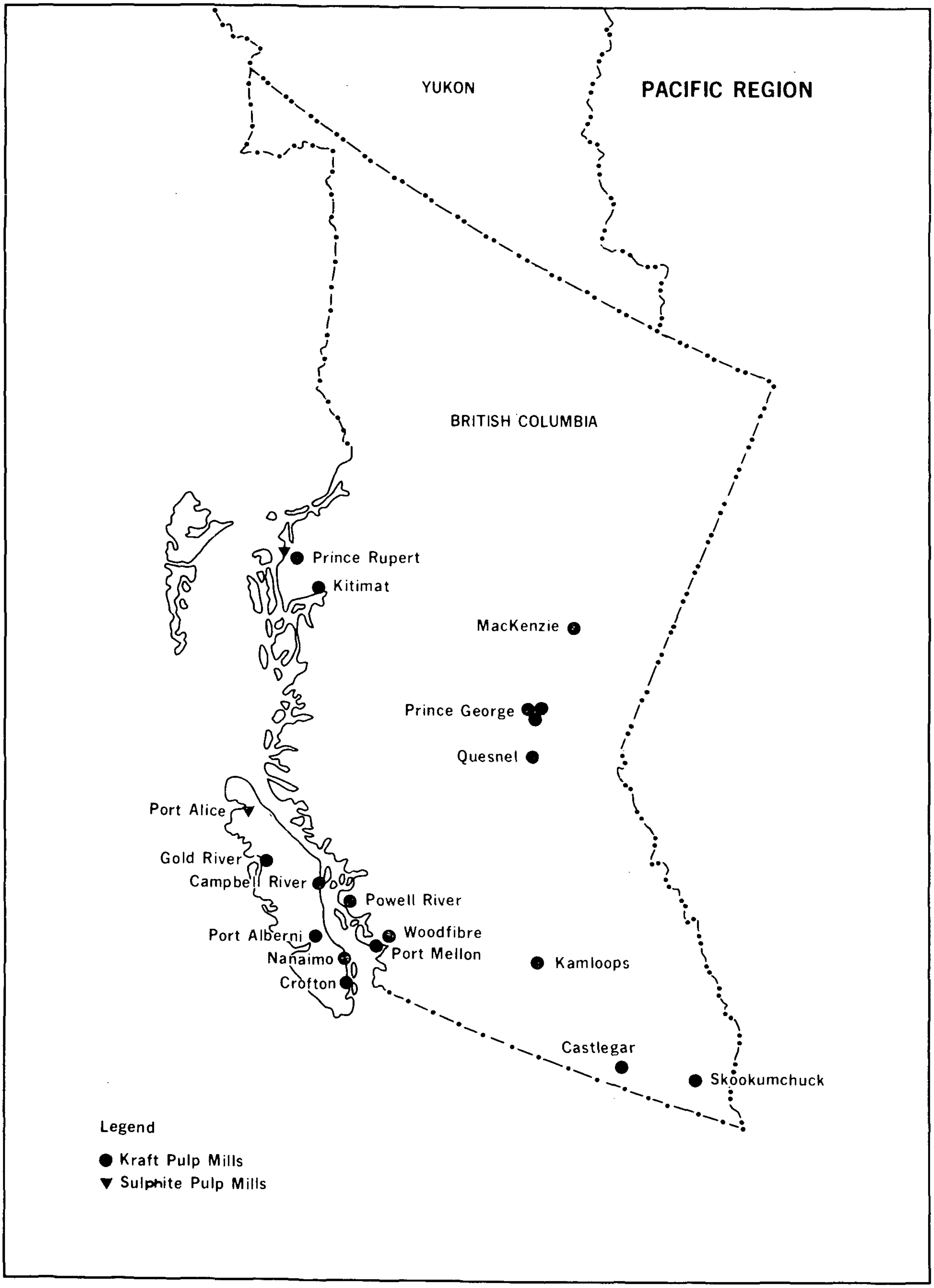
APPENDIX D: FIGURE 2



APPENDIX D: FIGURE 3



APPENDIX D:FIGURE 4



APPENDIX D: FIGURE 5