THE UNIVERSITY OF MANITOBA

ENVIRONMENTAL ASSESSMENT OF THE AIR POLLUTANT EMISSIONS FROM THE MANITOBA HYDRO THERMAL GENERATING STATION AT BRANDON, MANITOBA

by

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This paper presents an evaluation of the air pollutant emissions from the Brandon Generating Station. Emission rates were estimated using a materials balance of the combustion products versus the fly ash retained in the boilers and the dust collectors. Dispersion analyses were performed to determine the corresponding ground-level pollutant concentrations for a variety of meteorological conditions.

The major air pollution problem was found to be high concentrations of suspended particulate matter in excess of the Manitoba and National Air Quality Maximum Acceptable levels. This problem exists under virtually all conditions at full load. A reduction of 90 to 95% in the particulate emissions is required to effect compliance with the air quality standards.

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PREFACE

Air pollution technology is a relatively new field, with most of the major advances in analysis and control having been made during the past decade. Hence, many people in the environmental engineering field who are not directly concerned with air pollution have only limited knowledge in this area. An extensive introduction has therefore been included with this paper to provide some general background information on this topic. This will allow those less knowledgeable in the air pollution field to better understand the work presented here.

The opinions, conclusions, and recommendations expressed in this report are those of the author only and in no way reflect the policies or judgements of Environment Canada.

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1. INTRODUCTION

The practical assessment of an industrial air pollution problem is usually carried out in four major stages. These are: 1) source evaluation, 2) receptor evaluation, 3) dispersion analyses, and 4) abatement and control recommendations. These steps are briefly discussed below in order to give the reader an overview of the basic approach used in the Brandon evaluation. A more in-depth discussion of those fundamentals of each area applicable to the Brandon study then follows.

1.1 GENERAL APPROACH TO AIR POLLUTION ASSESSMENTS

1.1.1 Source Evaluation

The first step in evaluating an air pollution problem is an accurate assessment of the source or sources involved. This should include specification of the source parameters such as type and nature of pollutants, pollutant output rates, and the heights, temperatures, speeds, and volumes of the gas emissions.

1.1.2 Receptor Evaluation

The second step of the assessment is a receptor evaluation, wherein are specified those circumstances under which the pollutants could cause a problem. The receptor evaluation should also determine whether the effects of the air pollutants are likely to be dependent upon other variables, such as temperature, humidity, or time of day.

1.1.3 Dispersion Analyses

The third step involves the compilation and use of pertinent meteorological data in conjunction with the source information to arrive at a reasonable estimate of the dispersion patterns of the airborne effluents. The most suitable techniques now available for the quantitative approximation of air pollution problems emphasize ordinary, continuous stack emissions over relatively uncomplicated terrain. It must therefore be emphasized that dispersion calculations based on these techniques can only provide a first approximation in the analysis of a given situation.

The case of the worst conceivable conditions is usually considered first to determine whether any problem can possibly exist. A simple first approximation of this case is the calculation of the downwind pollutant concentration assuming the source to be a ground level under very stable atmospheric conditions (i.e. in a deep surface temperature inversion). If this first calculation does not indicate a problem situation, it can usually be assumed that no air pollution problem is ever likely to develop from the given source. If, however, the first estimate indicates potential trouble, then simulation of the stack effect is necessary. This is accomplished by calculating several cases which include a stack height term, to determine whether the maximum ground level concentrations are within an acceptable range. These estimates may be based first on the actual stack height alone, without any allowance for the buoyancy and momentum of the plume. Should these calculations yield results that are acceptable by a wide margin, and if there is no evidence that the source is subject to unusual terrain or meteorological conditions, no problem should exist. This is particularly true where it is certain that the plume will remain well above sensitive receptors under inversion conditions.

Failure of the last step to produce acceptably low concentration estimates necessitates the incorporation of more detailed computations into the study. This involves the use of terms to account for the buoyancy and momentum of the actual stack plume to obtain effective stack heights, with subsequently lower estimates of the maximum ground level concentrations. Where such refined estimates are required, it is usually necessary to calculate fairly complete ground level concentration patterns, in order to define values for sensitive receptor areas and to determine the probable frequency of occurrence of adverse air quality conditions. A first approximation can be based on general meteorological data for the given area and consideration of peculiarities of the locality. The probable effects of terrain and nearby elevated structures should also be taken into account when the assessment has reached this degree of sophistication.

Wind tunnel and/or tracer studies simulating the anticipated effluent behaviour are normally considered for air pollution studies only when the desired information cannot be determined by the previously outlined methods. Such sophisticated assessments are generally more expensive than calculated estimates and meteorological studies by about one order of magnitude.

1.1.4 Abatement and Control Recommendations

The final step in the analysis of an industrial air pollution problem concerns the recommendation of preventive or corrective measures which will ensure compliance of the pollutant source with regulatory air emission limits. The control of atmospheric emissions from a process may be effected by any of three general methods. These are: 1) process change, 2) fuel change, and 3) installation of control equipment.

A process change can be either a modification of the operating procedures for an existing process or the substitution of a completely different process. In some cases the least expensive control is achieved by completely abandoning the old process and replacing it with a new, less polluting process. A portion of the costs incurred in renovating an operation may be offset by any increased production and/or recovery of material.

For many operations the ideal solution to air emission problems is a change to a less polluting fuel. If, for example, a thermal power plant is emitting large quantities of sulfur dioxide and fly ash, conversion to natural gas may be cheaper than installing the necessary control equipment to reduce the pollutant emissions to acceptable levels. Fuel switching based upon meteorological or air pollution forecasts is practised in some areas as a means of reducing the air pollution load at critical times (1). Many control agencies allow power plants to operate on residual oil during certain times of the year when pollution potential is low. Some large power utilities convert to a more expensive, but lower sulfur coal when a high air pollution potential is forecast, e.g. during stagnation conditions.

The third option is the removal of specific air contaminants from the exhaust gases by incorporating control equipment into the process stream. This method of reducing the pollutant emissions is required in a great number of situations where sufficient emission reduction cannot be obtained by a fuel or process change, necessitating the reduction of pollutant levels in the exhaust gases prior to their release to the atmosphere. The equipment for the pollutant removal system includes all hoods, ducting, fans, controls, and disposal or recovery systems that might be necessary. Maximum efficiency and economy are achieved by engineering the entire system as a unit. Many systems operate at less than maximum efficiency because a portion of the system was designed or adapted without consideration of the other portions (2).

1.1.5 Summary

Clearly, the decision to opt for one or more of the control measures previously described is based on a compromise between meeting the requirements of regulatory air emission standards and the economics of doing so. Furthermore, consideration must also be given to future changes in the governing parameters, e.g. changes in the availability of a chosen fuel or future increased restrictions on air pollutant emissions.

1.2 AIR POLLUTANT EMISSIONS FROM THERMAL GENERATING STATIONS

1.2.1 Introduction

Thermal generating stations rank third in their contribution to air pollution in the United States. These power plants emit approximately 25% of the particulates, 46% of the sulfur oxides, and 25% of the nitrogen oxides in the United States. They are relatively minor contributors of carbon monoxide and hydrocarbons (3). In Canada utilities and power generation account for only 9.7% of the particulates, 6.7% of the sulfur oxides, and 13.0% of the nitrogen oxides emitted into the atmosphere. Carbon monoxide and hydrocarbon emissions from these sources are relatively small in Canada, totaling only $<$ 0.05% and 0.1%, respectively, of the total emissions for Canada of these contaminants (4). It can readily be seen from the above figures that power plants contribute a much smaller portion of the air pollution load in Canada than in the United States.

Power plants were recognized early to be sources of concentrated air pollutants, mainly because they are relatively few in number in comparison with other sources such as automobiles. Initially sulfur dioxide and particulate emissions were the items of primary concern, but more recently nitrogen oxide emissions have been given some consideration (2,3).

The different types of thermal power plants and their related air pollutant emissions are discussed in the section which follows. (Although the operation of nuclear power plants involves the production of heat to drive turbo-electric generators, the term "thermal power plants" as used in this discussion refers only to those power plants which rely on the combustion of fossil fuels (coal, oil, and natural gas) for heat).

1.2.2 Sources of Electrical Power

Electrical power utilities may be classified according to the energy source used for the generation of electricity. The three major types of power utilities are thermal, hydroelectric, and nuclear, in order of decreasing generating capacity in the United States. Current and projected distributions of electrical energy sources are given in Table 1.1. The figures in Table 1.1 indicate a large forecast increase in the use of nuclear energy, favoured by the anticipated development of breeder reactors, but the absolute growth in the generating capacity of fossil fuel plants will exceed that for nuclear plants. Hydroelectric sources are very limited in their growth potential, an unfortunate situation in view of the fact that they are virtually air pollution-free

1.2.3 Types of Fossil Fuel Power Plants

Thermal generating stations may be further classified according to the type of fossil fuel or fuels utilized. The major energy sources are coal, oil, and natural gas, as shown in Table 1.2. The data given show a forecast increase in all three categories. No dramatic change is indicated in the percentage use of each fuel type with the exception of the recent shift from the use of oil to natural gas.

Practically all use of fossil fuels for electrical power generation involves the production of steam to drive turbo-electric generators.

Gas turbines are being used to a limited degree for handling peak operating loads, but they are not expected to represent a significant fraction of the total power generating capacity in the future (3). Tables 1.1 and 1.2 predict a continued increase in fossil fuel use for power generation, and hence without a corresponding reduction in combustion product emissions from thermal generating stations, the air pollution contribution of these plants will also continue to increase.

1.2.4 Thermal Power Plant Construction and Operation

1.2.4.1 Boiler Construction and Capacity

Most thermal power installations utilize relatively large furnace boilers capable of producing several hundred thousand pounds of steam per hour per unit.

A boiler consists basically of a burner, firebox, heat exchanger, and a means of creating and directing a flow of gases through the unit. All combustion equipment of this type includes these essentials. Most also include some auxiliary systems, the number and complexity of which increase with the size of the units. Larger combustion equipment often includes flame safety devices, soot blowers, air preheaters, economizers, superheaters, fuel heaters, and automatic flue gas analyzers.

The boiler units used in power plants are typically 20 to 30 feet square by 80 to 100 feet in height. A typical coal-fired unit is shown in Figure 1.1. Variations in design deal primarily with the type and location of the coal-firing equipment. Figure 1.2 shows a typical oil or natural gas fired boiler. The same unit may be used to burn fuel oil, natural gas, or both simultaneously.