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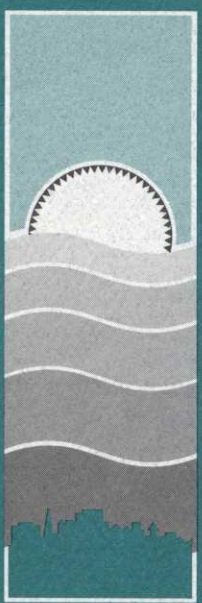
NATIONAL EMISSION GUIDELINES FOR STATIONARY COMBUSTION TURBINES



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The Canadian Council of Ministers of the Environment (CCME) is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national, international and global concern. The 13 member governments work as partners in developing nationally consistent environmental standards, practices and legislation.

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Glossary of Terms

Within the context of the Guideline, the meaning of certain terms is as described below.

Combustion Turbine: A combustion turbine is an engine which operates according to the Brayton thermodynamic cycle, in which fuel is burned and the products of combustion at a high temperature are allowed to expand through a rotating power turbine thus producing a net amount of motive power.

New Combustion Turbine: For the purposes of this Guideline, a new combustion turbine is defined as a unit which receives final provincial or regional regulatory environmental approval to construct on or after 30 November 1994.

Peaking Combustion Turbine: A peaking combustion turbine is a unit which is ordinarily used to supply electric or motive power at periods of high demand or during unforeseen outages. Such a unit will not usually operate more than 7500 hours in any 5 year period and, in those years, a total of no more than 3000 hours during the months of May, June, July, August and September.

As extraordinary circumstances warrant, special dispensation allowing additional unit operation may be sought from the appropriate provincial or regional regulatory authority.

Stand-By Combustion Turbine: A stand-by combustion turbine refers to a unit which is not required for the supply of energy or motive power to meet normal system operational requirements.

Combustion Turbine Facility: A combustion turbine facility includes the combustion turbine, the steam turbine (if applicable), the fuel handling equipment, related pollution control and flue gas handling equipment, and equipment required to directly recover energy from the exhaust gases. For simplification of thermal energy measurement, it excludes the downstream heating, cooling and industrial processes which utilize thermal energy recovered from the facility.

Power Rating: The power rating of a combustion turbine unit is the normal maximum continuous rating, in Megawatts, at ISO conditions as provided by the manufacturer.

ISO Conditions: International Standards Organization conditions refer to a reference state of 288 degrees K ambient temperature, 60 percent relative humidity and 101.3 kilopascals barometric pressure.

Thermal Efficiency: The fraction of the total energy input which is transformed into net useful energy output, usually expressed as a percentage on a lower heating value basis.

Lower Heating Value: Lower Heating Value of the fuel is the energy released during combustion of the fuel, excluding the latent heat content of the water vapour component of the products of combustion.

Auxiliary Burners: This refers to the use of equipment to burn various types of fuel in locations other than in the combustion turbine combustors.

Oxides of Nitrogen (NOx): NO_x refers collectively to nitric oxide (NO) and nitrogen dioxide (NO_2) expressed as a nitrogen dioxide equivalent.

Gaseous Fuel: A fuel which, as received, at atmospheric conditions is a gas.

Liquid Fuel: A fuel which, as received, at atmospheric conditions is a liquid.

Solid-Derived Fuel: A fuel which, as burned, is derived from biomass or by some process such as gasification or liquifaction of coal.

Abbreviations

CCME	Canadian Council of Ministers of the Environment.
MW	Megawatt of power.
g	Gram.
GJ	Gigajoule, (10^9) Joules of energy.
ppmv	Parts per million on a volume basis.
NO_x	Oxides of Nitrogen.
CO	Carbon Monoxide.
SO_2	Sulphur dioxide.

Preface

This Guideline has been established as part of the Canadian NO_X/VOC Management Plan issued in May of 1991 by the Canadian Council of Ministers of the Environment (CCME). Its objective is to encourage reductions in the emissions of oxides of nitrogen (NO_X) while minimizing collateral emissions of other pollutants from stationary combustion turbines. These types of engines are used as mechanical drives for gas compression, electric power production, and for other industrial processes. While this Guideline establishes minimum broad national emission targets for new stationary combustion turbines, it is acknowledged that provincial and regional environmental authorities may opt to impose more stringent standards in response to regional or local problems.

As opportunities arise, where existing combustion turbine units are to undergo major modifications apart from normal maintenance, improvements in NO_X emission performance should be evaluated. The assessment of proposed emission rates and control methods for existing units should be undertaken in close consultation with the appropriate provincial or regional regulatory authority. In this regard, proper consideration should be given to the limitations imposed by factors such as unit age and system operational requirements, as well as the overall environmental performance improvements that can accrue from enhanced energy efficiency.

For example, this could apply to major modifications such as:

- re-classification of peaking units to base load operation,
- upgrades of combustion turbines for use in combined cycle or facilities with solid-derived fuels, and
- replacement of major components, including the combustion system and turbine rotor, at the end of their normal operating lives.

This Guideline recognizes that improved environmental performance can be achieved by using advanced technological developments where practical, and seeks to encourage the application of the best technology with regard to energy efficiency. It is also noted that emissions will vary with the type and size of combustion turbine, and with the fuel being consumed. Therefore the Guideline incorporates distinct NO_X emission targets for various unit sizes and fuels.

The Guideline was developed through a multi-stakeholder consultation process, by a national working group consisting of representatives from industrial users and manufacturers of combustion turbines, as well as representatives from provincial and federal governments. The contributions of all participants who assisted in the establishment of this Guideline are gratefully acknowledged.

Inquiries on the Guideline may be directed to:

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Introduction

This National Emission Guideline encourages project proponents to develop and operate combustion turbine facilities in a manner which restricts emissions of oxides of nitrogen (NO_x), sulphur dioxide (SO_2), and carbon monoxide (CO).

The Guideline emission targets are expressed primarily as emissions by weight per unit of net useful energy output (grams per Gigajoule). In this approach, proponents of a project are required to account for their emissions and for the net useful energy output, represented by electrical or shaft power as well as exhaust thermal heat energy used by industrial processes and other users. The Guideline thereby emphasizes results and avoids prescribing how these are achieved. In this case the facility includes the combustion turbine itself as well as other processes and equipment used to directly recover energy from the fuel consumed in the facility.

To confirm that the combustion turbine facility is being operated in a manner which is consistent with the Guideline provisions, the project proponent should provide the appropriate facilities required to periodically or continuously monitor energy input and output flows and emissions, depending upon the application. While the burden of measuring and monitoring performance may be greater if all energy outputs are being considered, this approach provides an alternative method of reducing overall emissions while taking into account the environmental benefits of energy efficiency.

Applicability

This Guideline applies to all new combustion turbines as defined in the Glossary of Terms section of this Guideline.

The Guideline does not apply to the following cases:

- combustion turbines used for emergency or stand-by duty,
- combustion turbines used in research, development, and field demonstration,
- combustion turbines under repair or being tested.

In an unusual circumstance when a unit is to be used in a unique application where emission control technology can be demonstrated to be impractical, special dispensation to allow unit operation may be sought from the appropriate provincial or regional regulatory authority.

Although the emission guidelines apply to the primary fuel consumed by the combustion turbine facility, the proponent may also seek approval from the appropriate regulatory authority to operate for a limited amount of time on a secondary fuel at a higher emission level when the primary fuel supply is disrupted.

General Notes

Δ In the case where multiple new small combustion turbines are installed instead of a single large unit, the applicable unit size for the purposes of this Guideline will be the sum of the individual unit power ratings. While it is recognized that operational requirements may dictate the use of several units, multiple small units should not be used to evade the more stringent limits applicable to larger units.

Δ For units in the 3 MW to 20 MW size range in section 1 of the Guideline, an additional two-year transition period is provided to allow for development of advanced emission reduction technologies.

Δ In the case where a combustion turbine facility uses auxiliary burners, the Guideline limits apply to all fuel consumed by the facility, the fuel used in the auxiliary burners being treated as if it had been burned in the combustion turbine.

Δ To determine the useful energy output over and above electrical or shaft power production, it is only necessary to measure the difference between the energy of the thermal fluids leaving and returning to the combustion turbine facility, and to demonstrate that the bulk of this energy is extracted in a useful application. This avoids having to individually measure the energy consumed by each downstream thermal energy application process in determining the heat output allowance.

National Emission Guideline for New Stationary Combustion Turbines

1. Emissions of Oxides of Nitrogen

The emission targets for various types of combustion turbines are determined by calculation of the allowable mass of NO_x (grams) per unit output of shaft or electrical energy (Gigajoules), as well as an allowance for an additional quantity of NO_x emitted if useful energy is demonstrated to be recovered from the facility's exhaust thermal energy during normal operation. Allowable emissions over the relevant time period equal:

(POWER OUTPUT x A) + (HEAT OUTPUT x B) = grams of NO_2 equivalent

Where:

- Power Output is the total electricity and shaft power energy production expressed in Gigajoules (3.6 GJ per MW-hour).
- Heat Output is the total useful heat energy recovered from the combustion turbine facility.
- "A" and "B" are the allowable emission rates, expressed in grams per Gigajoule, for the facility's power and heat recovery components respectively, as summarized below.

POWER OUTPUT ALLOWANCE " A" (g/GJ)

NON-PEAKING TURBINES	Natural Gas	Liquid Fuel
Less than 3 MW	500	1250
3 - 20 MW (1)	240	460
Over 20 MW	140	380
PEAKING TURBINES		
Less than 3 MW	Exempt	Exempt
Over 3 MW	280	530

Notes:

(1) For the initial two-year period of implementation of the Guideline, the emission allowances for 3 - 20 MW sized non-peaking units are 350 g/GJ and 600 g/GJ, for gaseous and liquid fuels respectively.

(2) The value of "A" has been set at 500 g/GJ for solid-derived fuels which recognizes that the competing alternative technology option is a conventional coal-burning steam electric power plant.

HEAT RECOVERY ALLOWANCE "B" (g/GJ)

For All Units:	Natural Gas	40
	Liquid	60
	Solid-Derived	120

The Heat Recovery Allowance is a NO_x emission allowance for energy recovered from turbine exhaust gases as heat. The allowance corresponds to the emissions savings which result from not serving a heating or cooling load by burning additional fuel in an industrial boiler, but by recuperating heat during normal operation from combustion turbine exhaust gases and other sources of 'waste' heat such as condensate.

2. Emissions of Carbon Monoxide (CO)

For units which are covered by the NO_x provisions of this Guideline, emissions of CO corrected to ISO conditions at 15 percent oxygen and on a dry volume basis should not exceed:

- 50 parts per million at its power rating.

3. Emissions of Sulphur Dioxide (SO_2)

Sulphur dioxide emissions from combustion turbines can be limited by using low sulphur content fuels, or by using technologies which reduce the fuel sulphur content or which capture sulphur dioxide emissions in the exhaust. Sulphur dioxide emissions should not exceed:

Δ **For Liquid and Gaseous Fuel:**
For non-peaking units, 800 grams per Gigajoule of output, and for peaking units, 970 grams per Gigajoule of output, all based on the lower heating value of the fuel.

Δ **For Solid-Derived Fuels:**
770 grams per Gigajoule of output for those fuels whose uncontrolled SO_2 emissions based on fuel sulphur content would be between 770 and 7700 g/GJ of output, or a minimum of 90% sulphur capture for those fuels whose uncontrolled SO_2 emissions based on fuel sulphur content would be greater than 7700 g/GJ of output.

Δ Units with a power rating of less than 3 MW which are used exclusively to power natural gas field compressors upstream of natural gas processing facilities are exempt from the SO_2 limits.

4. Measurement and Monitoring

To confirm that the combustion turbine facility is being operated in a manner which is consistent with the Guideline provisions, the project proponent should provide the capability required to appropriately measure energy flows and emissions of the contaminants for which targets are stipulated. Energy flows include fuel consumption, electricity and shaft power, and the utilization of steam, condensate and other thermal fluids within the facility. As well as direct measurement of emissions, operators should regularly measure fuel properties including heating value and sulphur content.

For non-peaking combustion turbine units larger than 25 MW which produce electricity, emissions should be measured by continuous emissions monitoring, or by a method of comparable effectiveness to continuous monitoring, subject to approval by the appropriate provincial or regional regulatory authority. For other units, emissions should be monitored as required by the appropriate regulatory authority, but as a minimum, as part of initial commissioning, following a major service outage or modification, or at least once every year.

Methods for measuring emissions should be as specified by the appropriate regulatory authority, but at a minimum should be consistent with those developed and published for this purpose by Environment Canada.

Appendix A
Working Group Members List

Provinces

Jane MacNeill	Nova Scotia Department of Environment
Denis Maftei	Ontario Ministry of the Environment
Randy Dobko	Alberta Environment
Kamal Bhattacharyya	B.C. Ministry of Environment, Greater Vancouver Regional District

Turbine Users

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Bill Peel	Alberta Power
David Gass	Saskatchewan Power
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Jake Brooks	Independent Power Producers Society of Ontario
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Manufacturers

Peter Handy	Rolls Royce (Canada) Limitée
Ed Theissen	Asea Brown Boveri
Glen Kennedy(1)	General Electric Canada Inc.
Lawrence Kaempffer	Westinghouse Canada Inc.
Kenneth Walls(2)	Solar Turbines Canada, Ltd.

Federal Government

Dwayne Bateson	Energy, Mines and Resources Canada
Keith DePooter	National Research Council of Canada
Pierre Pinault	Environment Canada
Chris Doiron(3)	Environment Canada
Manfred Klein	Environment Canada

(1) Replaces Mike Kennedy, now with H.A. Simons Ltd.
(2) Replaces Cary Alexander; with assistance from Dave Phaneuf
(3) On assignment from New Brunswick Power

Environment Canada and the CCME extend their heartfelt appreciation to Cary Alexander and Brian Hoyland of Solar Turbines, both of whom regrettably passed away during 1991. Their assistance was instrumental in the development of the Guideline.

Appendix B
Illustrative Example of NOx Guidelines for Various Unit Sizes and Overall Plant Efficiencies

The National Emission Guidelines for Stationary Combustion Turbines are based upon allowable emissions of oxides of nitrogen (NO_x) by weight per unit of useful energy output, expressed in units of grams per Gigajoule (g/GJ). To aid in the conversion of these expressions to another commonly used form, a volumetric basis assuming a dry exhaust with 15 percent oxygen content (ISO ppmv), the following illustrative example is provided.

Figure 1 shows examples of how NO_x emissions expressed as ppmv (ISO) may be related to a combustion turbine facility's overall plant thermal efficiency, based upon the emission allowances (g/GJ) of section 1 of the Guideline. For each particular case of turbine size and fuel source, the initial slope of the line represents operation in a simple or combined cycle mode, determined by the Power Output Allowance 'A'. The latter portion represents an additional allowance for thermal energy utilisation in a cogeneration plant, as determined by the Heat Recovery Allowance 'B'. For simplicity, a combined cycle efficiency of 50 percent has been assumed for all unit sizes. The actual relationship will vary according to each proponent's plant design.

Assumptions:
1 ISO ppmv = 1.70 grams NO_2 per GJ of heat input, for natural gas fuel
= 1.77 grams NO_2 per GJ of heat input, for liquid fuel

Example:
A turbine producing 25 MW, or 90 GJ/hr, at a thermal efficiency of 35% in a gas-fired simple cycle application will consume 257 GJ/hr of fuel gas. It will have to meet a 140 g/GJ emission target. On a volumetric basis, this corresponds to a 29 ppmv level, and it could produce about 12.6 kilograms per hour of NO_2 equivalent;

$$140 \text{ g/GJ output} \times .35 \frac{\text{GJ output}}{\text{GJ input}} \times \frac{1}{1.7} = 29 \text{ ppmv}$$

$$140 \text{ g/GJ output} \times 90 \text{ GJ/hr output} = 12\,600 \text{ g/hr } NO_2$$

In a combined cycle application, a 50 percent efficiency would allow it to meet a 41 ppmv level while generating 129 GJ/hr of power, so that it could produce about 18 kg/hr of NO_2.

In an 80% efficient cogeneration cycle, an additional 77 GJ/hr of thermal energy can be used. The 40 g/GJ heat recovery allowance would permit the plant to produce an additional 3.1 kg/hr of NO_2, and would result in an additional (3.1/18) = 17% NO_2 concentration, or 7 ppmv, for a total emission level of about 48 ppmv. The use of auxiliary burners will increase fuel consumed and may affect the allowable emission rate.

GAS TURBINE EMISSION GUIDELINES

Sample Conversion From grams/GJ to ppmv

(for non-peaking units)