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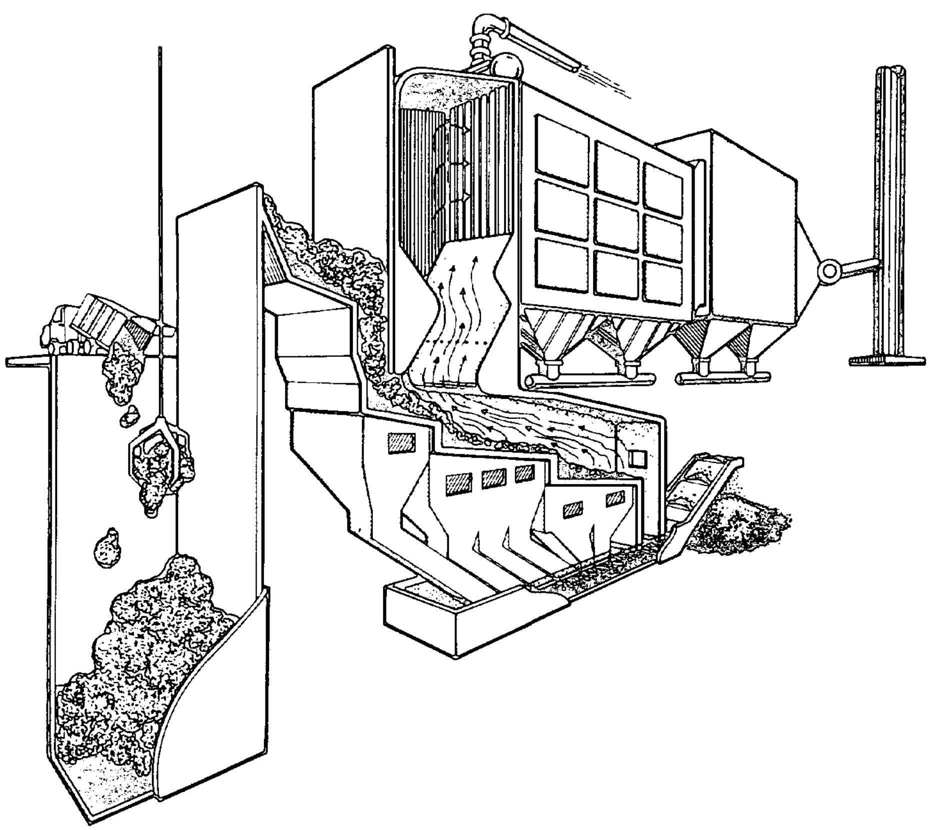
Operating and Emission Guidelines for Municipal Solid Waste Incinerators

Report CCME-TS/WM-TRE003

June 1989



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OPERATING AND EMISSION GUIDELINES FOR MUNICIPAL SOLID WASTE INCINERATORS

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1 INTRODUCTION

1.1 Purpose

Recognizing the potential for significant growth of municipal solid waste (MSW) incineration and the health and environmental concerns associated with such facilities, the Waste Committee of the Canadian Council of Resource and Environment Ministers (CCREM) established a national committee to develop MSW incineration guidelines. The terms of reference for and objectives of this committee were as follows:

1) in consideration of the most up-to-date information on municipal solid waste, energy-from-waste combustion and related emission control systems, to define the most suitable control technology and establish target emission values for selected parameters;

2) to consider parameters for control in four categories of contaminant emissions:

Trace Organics	-	polychlorinated dibenzo-*para*-dioxins (PCDD)
	-	polychlorinated dibenzofurans (PCDF)
	-	polychlorinated biphenyls (PCB)
	-	polycyclic aromatic hydrocarbons (PAH), etc.
Trace Metals	-	mercury, cadmium, lead, etc.
Acid Gases	-	hydrochloric acid, hydrofluoric acid, sulphur oxides, nitrogen oxides
Conventional	-	particulate, carbon monoxide, carbon dioxide, opacity, etc.

3) to make recommendations for the handling and disposal of residual ash or other solid or liquid phase residues from the incineration process;

4) to identify and recommend both monitoring and surveillance procedures for the parameters considered and define the frequency of these activities.

5) to incorporate recommendations for the design and operation of combustion technologies along with a definition of Best Management Practices (BMP);

6) to complete the definition of the most suitable control technology in draft by December 31, 1987, and a final document within six months of that date;

7) to complete the technical support and Best Management Practices document by December 31, 1988; and

8) to address small municipal solid waste incineration systems, with and without energy recovery, and to prepare recommendations.

This report was submitted to the CCREM Waste Committee as the formal response to the terms of reference.

1.2 Background

In response to the ever-increasing amounts of municipal solid waste (MSW) generated in Canadian communities every day and the need to explore waste management options other than landfills, many municipalities are considering energy-from-waste (EFW) incinerators. Energy-from-waste incinerators fired with MSW offer the opportunity to reduce the amount of material that must ultimately be landfilled while at the same time obtaining usable energy.

Although the prospect of waste incineration has caused considerable concern in some communities, much of this concern is based on information about the emissions generated by old and/or poorly operated facilities. Communities across Canada are seeking advice on waste management and particularly incineration. A definition of the elements of a well designed and properly operated incineration system, and the capabilities and limitations of such systems, is required to address these concerns.

While the effects of any combustion device on the environment depend upon many factors, the major factors include the nature, form, and concentration of the materials released. For MSW incineration, the main releases are the flue gas, ash residues from combustion and emission control processes and, occasionally, process wastewater.

1.3 Scope and Limitations

Based on the variable characteristics of MSW and the contaminants released during incineration, the following substances were selected for consideration in preparing these guidelines:

Acid Gases

Hydrogen chloride	Oxides of nitrogen
Hydrogen fluoride	Oxides of sulphur

Metals

Cadmium*	Iron
Beryllium*	Lead*
Molybdenum	Chromium*
Calcium	Nickel*
Vanadium*	Silicon
Aluminum	Titanium
Magnesium	Boron

Barium	Phosphorus
Potassium	Mercury*
Sodium	Arsenic*
Zinc*	Antimony*
Manganese	Bismuth
Cobalt	Selenium*
Copper*	Tellurium
Silver	Tin

* Metals selected as most important for health and the environment.

Organics

Polychlorinated dibenzo-*para*-dioxin and polychlorinated dibenzofurans in the following homologue groups:

T	tetra	Hx	hexa	O octa
Pe	penta	Hp	hepta	

Chlorobenzenes (CB)

Cl-2 benzene	Cl-5 benzene
Cl-3 benzene	Cl-6 benzene
Cl-4 benzene	

Polychlorinated Biphenyls (PCBs)

Polycyclic Aromatic Hydrocarbons (PAHs)

Acenaphthylene	Benzo(e)pyrene
Acenaphthene	Benzo(a)pyrene
Fluorene	Benzo(b)fluoranthene
Phenanthrene	Benzo(k)fluoranthene
Anthracene	Perylene
Fluoranthene	Indeno(1,2,3-cd)pyrene
Pyrene	Dibenzo(a,h)anthracene
Chrysene	Benzo(g,h,i)perylene
Benzo(a)anthracene	Benzo(l)phenanthrene

Chlorophenols (CP)

Cl-2 phenol	Cl-4 phenol
Cl-3 phenol	Cl-5 phenol

Other

Particulate matter	Total hydrocarbons
Opacity	Oxygen

In addition to other specific physical and chemical properties of each potential release stream, information on the leaching characteristics of the ash residues, as well as processes to prevent leaching and the possible effects of such processes, were evaluated.

In developing guidelines, a number of considerations were addressed:

- limitations were placed upon the types of units covered by the guidelines;
- units of measurement for emission levels were defined;
- sampling and analytical methods were reviewed;
- different incinerators and control systems were examined;
- system performance was assessed; and
- facility costs were reviewed.

Before outlining the various decisions and guidelines, several general conditions must be addressed.

These guidelines should be considered minimum requirements applicable to all facilities larger than a specified size. Each jurisdiction should establish its own size limit based upon local socio-economic, population and geographic constraints. Site-specific considerations may require that a jurisdiction adopt special design features not specified in these guidelines.

As a matter of principle, all existing units will be required to meet the guidelines in the long term. The timing is site-specific and subject to each jurisdiction's priorities.

The guidelines do not address the issue of compatibility between recycling/reuse scenarios and incineration; these must be considered locally. The Committee does recognize, however, the important role that reduction, recovery, recycling and reuse must play in the eventual control and disposal of MSW. Municipalities are encouraged to evaluate the current activity and forecast potential of these programs in the community before embarking upon an energy-from-waste (EFW) project.

The Committee has specifically endorsed a ban on new small-scale residential, commercial, and institutional incinerators that are not capable of meeting minimum combustion requirements. Furthermore, it recommends the phasing out of existing systems if they are similarly incapable of meeting the minimum standards. The Committee has also stated that pit burners should be banned for use in MSW disposal.

While the guidelines address the control of air emissions, they do not make specific recommendations on wastewater treatment or ash disposal. The Committee believes that most plants can be designed with "zero discharge" systems for water. Ash quenching consumes large quantities of water, providing a means for disposing of plant process wastewater streams. This is not a completely closed system but the impact of such releases is considered to be acceptable. Should plants require overflow capability to the municipal sewer system, water leaving the plant should be treated to ensure it meets permitted sewer discharge limits.

Although general guidelines on separation and handling of ash are provided, more specific guidance on ash disposal will be provided in a later document.

2 MEASUREMENT OF EMISSIONS

The units of measurement used for reporting air emission levels vary widely, as do the reference conditions for reporting these emissions. The following convention has been adopted in these guidelines.

The emission objectives in the guidelines are expressed in relation to dry cubic metres of flue gas at 25°C and 101.3 kPa (atmospheric pressure). Therefore, concentrations of contaminants in this document are expressed as:

$$\text{"x" mass/Rm}^3$$

where R refers to the above flue gas reference conditions. When considering gas concentration data in parts per million dry volume (ppmdv) the gas is assumed to be at the same reference conditions.

In addition to reference temperature and pressure conditions, the degree of dilution air in the gas stream is defined as 11 per cent (by volume) of oxygen, designated as "11% O_2". A flue gas composition of 11 per cent oxygen is close to the level achieved in most incineration systems at typical excess air levels.

Examples of emission data conversion are provided in Appendix A.

3 SIZE AND SITE CONSIDERATIONS

While it can be argued that all MSW incinerators should be required to meet the same standards, the socio-economic impact of such regulations may be significant. Examination of the cost of installations equipped with the recommended air pollution control equipment shows that the cost of control equipment for smaller units may equal or exceed the cost of the incinerator. Part of this is the cost of a boiler or equivalent flue gas temperature reduction system.

Notwithstanding the need to evaluate the cost-effectiveness of small-scale incinerators, the Committee has suggested that each jurisdiction establish its own cut-off limit for application of these guidelines. Smaller units must be designed to meet the same combustion conditions as the larger units in order to limit the release of many toxic contaminants. Units should also meet all other operating requirements such as loading levels and record keeping. Provinces may adjust the limits for air emissions from small facilities to levels demonstrated to be achievable on well-run units.

Care should be exercised in locating smaller facilities to minimize the number of incinerators in one area. Communities are encouraged to develop large centralized facilities to maximize the cost effectiveness of MSW incinerators.

Background or pre-construction environmental monitoring should be carried out at the proposed location of an incineration facility. Establishing the background emission levels before the plant goes into operation will enable future changes to be identified and comparisons to be made with the emissions from the plant. The effects of the waste incineration facility can be determined from such comparisons. The scope of background monitoring will be determined by the local jurisdiction.

4 DESIGN STANDARDS

4.1 General

In the conceptual stages of any development, it is necessary to establish a basic design/operating philosophy for the project. The following sections provide such a basis for MSW incinerator facilities. All aspects of the facility are considered including:

- combustion requirements;
- combustion control;
- air pollution control system requirements;
- air emission guidelines;
- anticipated air emission levels;
- noise control;
- ash management;
- wastewater management; and
- monitoring.

Incorporation of the following recommendations into the basic design of the incineration facility should ensure that the plant is capable of meeting its performance requirements.

4.2 Incinerator Design

Incinerator design must incorporate measures to ensure satisfactory combustion efficiency. This can be accomplished if an acceptable combination of temperature, residence time and gas mixing is achieved in the combustion zone.

The temperature generated in the combustion zone is a function of the heating values of the waste and the auxiliary fuel, the incinerator design, the air supply, and the combustion control. The actual temperatures achieved depend on heat losses. Heat losses include those from conduction (the transfer of heat through the walls of the incinerator), radiation and convection losses at the surface, and convection losses due to the exit of the products of combustion and the heating of the incoming air/fuel mixture, the amount of excess air, and the rate of release of energy in the fuel. Although the reaction rates of combustion increase rapidly with higher temperatures, the upper temperature in a system is normally limited by the materials used to construct the incinerator.

The effectiveness of the combustion process and, to a certain extent, the temperature achieved in the system depend on good mixing of air and fuel in the incinerator. This mixing is usually achieved by ensuring that the air being supplied to the combustion zone has sufficient momentum to penetrate the combustion gases.

Retention time, or the length of time available to ensure complete mixing of air and fuel, is an important incinerator parameter. The incinerator volume also must be large enough to allow fuel and combustible gases to fully mix and burn.

The design standards recommended for mass-burn incinerators in these guidelines are not intended for application to developing technologies. The recommendations provided are based on present day information and should be reviewed in light of ongoing studies. Even fluidized bed systems require more study to confirm major operating parameters. If, for example, a specific system can be demonstrated to achieve the same destruction efficiency at a temperature lower than 1000°C, a new "system-specific" lower temperature limit can be established.

Design guidelines for the three common incinerator systems (modular combustion unit, mass burn single chamber and refuse derived fuel) are summarized in Table 4.1. The significance of the various parameters is addressed in the following recommendations.

4.2.1 Minimum Temperature. Municipal solid waste (MSW) incinerators should be designed to maintain a temperature high enough to ensure organics destruction. The minimum temperature of 1000°C should be measured in conjunction with the minimum retention time as specified in recommendation 4.2.2.

4.2.2. Minimum Retention Time. MSW incinerators should be designed for a combustion gas residence time of not less than one second at 1000°C, calculated from the point where most of the combustion has been completed and the incineration temperature has been fully developed. In multi-chamber incinerators residence time is calculated from the secondary burner(s) flame front or final secondary air injection point(s). Where the furnace is one continuous space, such as in the spreader stoker and the single chamber mass burning designs, the location of the complete combustion/fully developed temperature point shall be determined by an overall design review.

4.2.3 Primary Air. The design should ensure that appropriate air distribution is provided to promote good contact between burning waste and incoming air. Control systems should provide the capability to adjust the distribution of the air and also maintain distribution of primary air to compensate for irregular fuel loading patterns on the grate. The controls must also be capable of limiting the air flow to an appropriate level to minimize particle entrainment and to reduce the possibility of quenching the

TABLE 4.1 DESIGN GUIDELINES FOR MUNICIPAL SOLID WASTE INCINERATORS

	Combustion Technology			
	Modular			
Parameter	Starved Air	Excess Air	Mass Burn	Refuse Derived Fuel
Minimum Temperature	1000°C	1000°C	1000°C	1000°C
Minimum Retention Time	1 second after final secondary air injection port	1 second after final secondary air injection port	1 second at 1 metre above last air injection ports	1 second at 1 metre above last air injection ports
Primary Air Supply	multi-port injection	multi-port injection	multiple plenums with individual air flow control	air distribution matched to waste distribution
Secondary Air Capacity	up to 80% of total air required	as required by design	at least 40% of total air required	at least 40% of total air required
Auxiliary Burner Size	60% of total rated heat capacity	60% of total rated heat capacity	60% of total rated heat capacity	60% of total rated heat capacity
Oxygen at Boiler Outlet	6 to 12%	6 to 12%	6 to 12%	3 to 9%
Turndown Restrictions	80 to 110% of design capacity	80 to 110% of design capacity	80 to 110% of design capacity	80 to 110% of design capacity
Maximum Carbon Monoxide (4-h rolling average)	50 ppmdv (57 mg/Rm^3) @ 11% O_2	50 ppmdv (57 mg/Rm^3) @ 11% O_2	50 ppmdv (57 mg/Rm^3) @ 11% O_2	100 ppmdv (114 mg/Rm^3) @ 11% O_2

Note: These are guidelines only; incinerator systems with operating parameters outside these ranges that meet the stack discharge limits would be acceptable.

combustion reaction. For modular incinerators, multi-port injection will meet these requirements. Multiple plenums with individual air flow control must be provided for mass burning incinerators, while in refuse derived fuel incinerators, the air distribution must be matched to the waste distribution.

4.2.4 **Secondary Air.** A secondary air supply system should be provided to promote mixing and allow for completion of the combustion process. The design of the air injection ports and the amount of the overfire air will depend on the furnace configuration and type of incinerator; however, the design should ensure good penetration and mixing under all flow conditions. The system should be designed for maximum secondary air capacity and flexibility, recognizing that it may be desirable to restrict the air flow to control the incineration process.

4.2.5 **Auxiliary Burner Size.** The auxiliary burner should have sufficient capacity to reach operating temperature on start-up and maintain it during shutdown. The auxiliary burner minimizes emissions by heating the system before waste is charged to the incinerator, and by providing additional heat to complete combustion during upset conditions. It is recommended that the auxiliary burner be capable of providing 60% of the total rated heat capacity.

4.2.6 **Oxygen at Boiler Outlet.** To minimize quenching or mixing problems, the recommended range for oxygen at the boiler outlet is 6 to 12% for modular and mass burning incinerators, and 3 to 9% for refuse derived fuel incinerators.

4.2.7 **Turndown Restrictions.** Incinerators should be designed to achieve the temperature, residence time, oxygen availability and mixing requirements over the complete expected range of values of the incinerator operating parameters, including:

- feed rate, ultimate analysis, heating value, ash and moisture contents;
- combustion air;
- flue gas flow rates; and
- heat losses.

Without verification of the performance of the incinerator, operation should be restricted to 80% to 110% of the rated design capacity.

4.2.8 **Maximum Carbon Monoxide.** Low carbon monoxide levels are an indication of good combustion. To achieve good combustion and low trace organic emissions, the recommended maximum carbon monoxide level for modular and mass burning incinerators is 50 ppmdv (57 mg/Rm^3) at 11% oxygen, calculated as a four-hour rolling average, and for refuse derived fuel incinerators, 100 ppmdv (114 mg/Rm^3) at 11% oxygen, also calculated as a four-hour rolling average.

4.3 Air Pollution Control System

Results of the National Incinerator Testing and Evaluation Program (NITEP) (1) and other test data have shown that low emissions of trace metallic and organic species occur when the operating temperature of the air pollution control (APC) system is low and the particulate matter removal efficiency is high. The following guidelines are therefore proposed for APC systems.

4.3.1 **Temperature.** The inlet temperature for the particulate matter control device should be approximately 140°C to ensure condensation of trace organic and metallic species. This value represents a good compromise between removal efficiency and operating reliability.

4.3.2 **Opacity.** Opacity in the incinerator stack should not exceed 5%. This readily monitored indication of the performance of the particulate matter control device provides the operator with advance warning of system failures. While it is not anticipated that opacity levels would exceed 1 to 2% under normal operation, values greater than the guideline indicate a need for additional performance evaluation.

4.4 Stack Discharges

4.4.1 **Discharge Limits.** Experience has shown that, when emissions of certain key contaminants are controlled, concentrations of other contaminants in emissions are lowered at the same time. A number of key contaminants are therefore subject to the stack discharge limits presented in Table 4.2.

While efficient combustion is a most important factor in minimizing carbon monoxide levels and reducing emissions of dioxins and furans, a good post-combustion control system is necessary to ensure that releases of these and other contaminants do not exceed the prescribed limits. The limits proposed for hydrochloric acid and particulate can be met with the best demonstrated control technology consisting of acid gas control systems equipped with fabric filter particulate control. Should other methods be developed and demonstrated to produce equivalent results, they would also be considered best demonstrated technology for air pollution control.

4.4.2 **Anticipated Emissions.** Good combustion control coupled with best demonstrated control technology form the basis of the anticipated emission

TABLE 4.2 STACK DISCHARGE LIMITS (at 11% oxygen)

Contaminant	Limit	Monitoring Method/ Averaging Time
Particulate Matter	20 mg/Rm^3	As specified by regulatory agency
Hydrogen Chloride (HCl)	75 mg/Rm^3* (50 ppmdv) or 90% Removal	Continuous Emission Monitor (24-hour Rolling Average)
Carbon Monoxide (CO)	57 mg/Rm^3** (50 ppmdv)	Continuous Emission Monitor (4-hour rolling average)
Total polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans	0.5 ng/Rm^3*** (Toxic Equivalency Factor new International Method, see Appendix B)	As specified by regulatory agency (3-test average)

* The least restrictive of these requirements apply.
** RDF systems should maintain a limit of 114 mg/Rm^3 (100 ppmdv).
*** Based upon isomer specific analytical test data; however, if only homologue test data are available, then the most conservative (largest) equivalency factor should be applied.

concentrations presented in Table 4.3. Systems burning normal MSW and in full compliance with the criteria presented in Table 4.2 should achieve the emission levels identified in Table 4.3.

Sulphur dioxide releases from MSW incinerators are highly variable because they reflect the sulphur content in the waste. Generally the sulphur content of MSW is low. Sulphur dioxide will react with the reagent used in the APC device. If hydrogen chloride is removed with 90% efficiency, data indicate that approximately 70% of the sulphur dioxide will also be removed. Test data suggest that typical 24-hour average concentrations will be approximately 260 mg/Rm^3 at 11% oxygen (100 ppmdv).

Since data on hydrogen fluoride concentrations are limited, no emission level has been predicted.

Concentrations of oxides of nitrogen are anticipated to be 400 mg/Rm^3 at 11% oxygen (210 ppmdv).

TABLE 4.3 ANTICIPATED EMISSIONS FROM MUNICIPAL SOLID WASTE INCINERATORS OPERATING UNDER GOOD COMBUSTION CONDITIONS AND EQUIPPED WITH DRY SCRUBBER FABRIC FILTER SYSTEMS (concentrations at 11% oxygen)

Contaminant	Typical Concentrations
Sulphur Dioxide	260 mg/Rm^3 (100 ppmdv)
Oxides of Nitrogen (NO_x as NO_2)	400 mg/Rm^3 (210 ppmdv)
Lead	50 $\mu g/Rm^3$
Cadmium	100 $\mu g/Rm^3$
Mercury	200 $\mu g/Rm^3$
Arsenic	1 $\mu g/Rm^3$
Chromium	10 $\mu g/Rm^3$
Polyaromatic Hydrocarbons	5 $\mu g/Rm^3$
Polychlorinated Biphenyls	1 $\mu g/Rm^3$
Chlorophenol	1 $\mu g/Rm^3$
Chlorobenzene	1 µg/Rm3

Trace metals emissions have been shown to correlate closely with particulate matter emissions. Effective control of lead and mercury, however, requires appropriate flue gas cooling and is part of the rationale for recommendation 4.3.1.

The other trace organic emissions will behave in a manner similar to PCDD and PCDF. Emission levels will be low if combustion and APC performance levels are good. Since some trace organics have an affinity for particle surfaces, improving particulate matter removal rates will further reduce emissions of these species. Levels listed in Table 4.3 have been achieved during limited test programs(1).

4.5 Noise Control

In designing MSW incineration facilities, measures should be taken to control noise levels to ensure compliance with local noise by-laws. Noise should be limited and at least consistent with ambient levels in the immediate area.

4.6 Ash Management

The following recommendations are interim management practices, pending further study of ash handling and disposal.

4.6.1 Characterization. It is recommended that residue characterization tests be conducted to enable an effective evaluation of management options. The residue from an incinerator consists of bottom ash, fly ash and any other solids collected inside equipment downstream of the incinerator unit. The physical and chemical characteristics of these residues must be determined because residue from an incineration facility may be hazardous. While various pass/fail tests may be applied to determine whether the residue is hazardous or non-hazardous, more extensive testing is recommended.

4.6.2 Fugitive Emissions. Adequate precautions should be taken to minimize fugitive emissions during the handling and transfer of incinerator ashes and other solid residues. These measures should include but are not limited to:

- the use of closed systems to handle fine dry materials until they can be mixed with liquids to minimize their dispersal into the atmosphere; and
- the use of watertight closed or covered containers for the transfer of residues from the plant to a landfill site.

4.6.3 Disposal. It is recommended that bottom ash residue be collected, stored and transported separately from the fly ash residue streams. The species and properties of the trace inorganic substances present in the fly ash appear to be different from those in the bottom ash.

Bottom ash residue is considered to have chemical and physical properties that should permit its disposal in a conventional municipal landfill. The actual disposition of the bottom ash residue in the landfill site would be determined by the local jurisdiction.

Fly ash residues should not be mixed with municipal solid waste; disposal in a conventional MSW landfill is not recommended without further treatment.

4.7 Wastewater Management

It is recommended that, to the greatest extent possible, wastewater discharges from MSW incinerators be eliminated and, where likely or necessary, appropriate treatment processes be installed to enable compliance with provincial or municipal limits.

A typical wastewater flow diagram for an incinerator with heat recovery is presented in Figure 4.1. Although few MSW incineration designs produce any significant

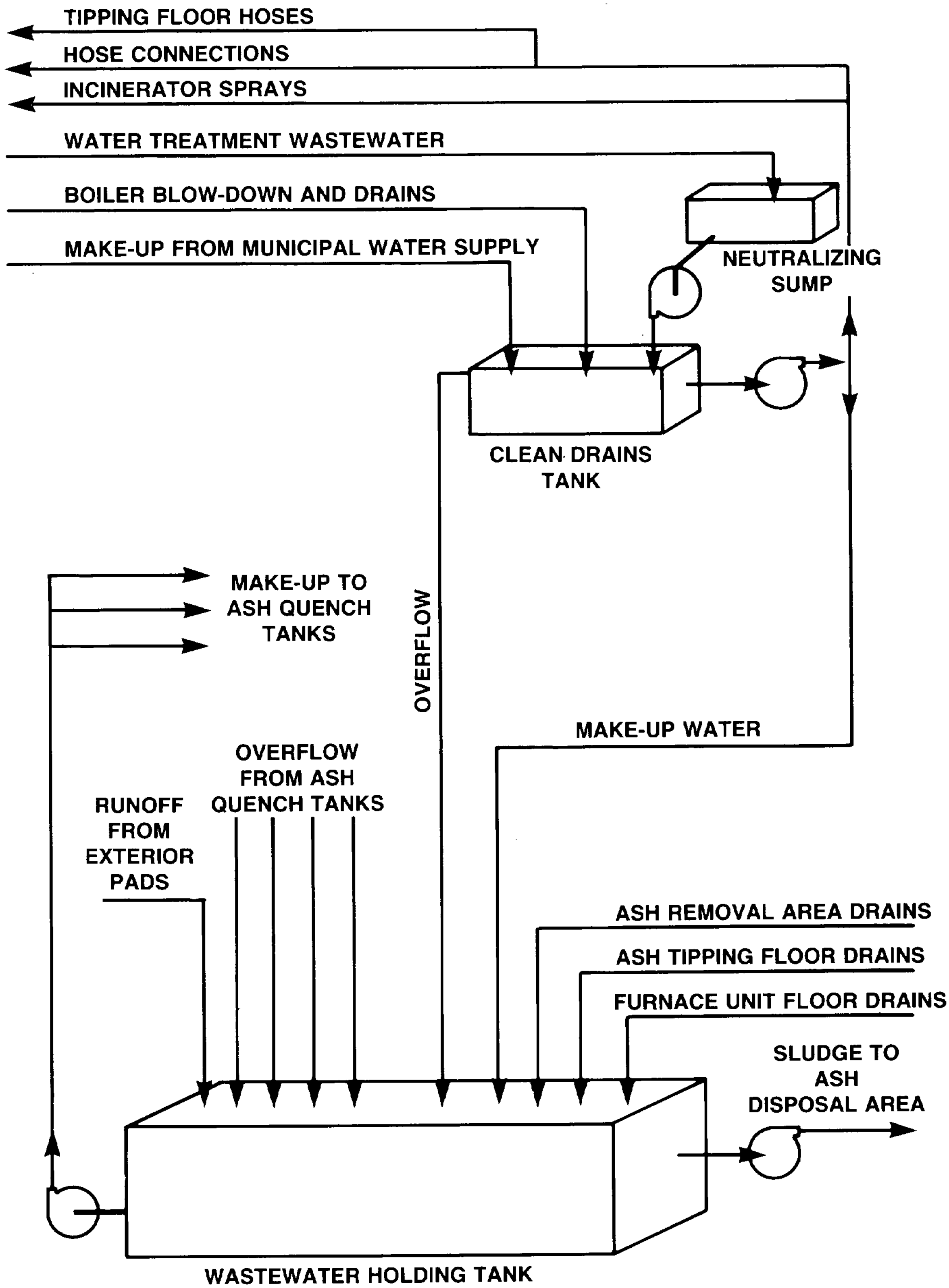

FIGURE 4.1 TYPICAL WASTEWATER FLOW DIAGRAM FOR MUNICIPAL SOLID WASTE INCINERATOR

quantities of wastewater, some streams can be generated by quench systems, conveyance systems, or wet scrubber processes. Shutdowns or equipment failures could cause discharges of these wastewaters to occur. Whether the discharge is directly to a receiving water or to a municipal sewer system, discharge limits must be met and, in most cases, this will make treatment of the wastewater necessary.

4.8 Monitoring and Control Systems

4.8.1 General. The monitoring equipment should be on-line whenever the incinerator is in operation, and during start-up and shutdown. Monitors can require maintenance and repairs more often than the process equipment; based upon standard practice the recommended monthly availability factors for all monitors is 95%.

A continuous emission monitoring (CEM) system should be installed to measure and record the following parameters:

- opacity;
- oxygen;
- carbon monoxide;
- hydrogen chloride; and
- temperature.

4.8.2 Process Monitoring. Process monitoring systems for incinerators should be sufficient to ensure that the requirements set out in this guideline are being met consistently. The monitors should be capable of signalling poor operation so that corrective action can be taken or the incinerator can be shut down.

Continuously monitored incinerator parameters should include temperature, carbon monoxide, and oxygen. The temperature should be measured at the end of the designated residence zone described in recommendation 4.2.2. Carbon monoxide and oxygen should be measured after the boiler to minimize sampling and gas conditioning problems.

The continuous carbon monoxide monitor should activate a visual and audible alarm when the four-hour rolling average carbon monoxide concentration exceeds that specified in recommendation 4.2.8. The continuous oxygen monitor should also have an alarm set point that will activate visual and audible alarms if the oxygen level drops below the oxygen range prescribed in recommendation 4.2.6.

The oxygen and carbon monoxide monitors should provide one average reading per minute for each analyzer based on an analyzer scan frequency of five seconds or less, and the average of four integrated values per hour, each collected for no less than three minutes in every fifteen minutes. Rolling averages are to be calculated from these data.

The air pollution control system should be equipped with temperature monitors and alarms suitable for indicating a potential failure of the gas conditioning system. Audible and visual alarms should be set to trigger upon a significant temperature change ($\pm$20°C).

Temperature both at the combustion zone and the fabric filter inlet should be the hourly average data integrated from measurements taken every ten seconds.

4.8.3 In-stack Monitoring. Continuous flue gas monitoring should be provided for:

- opacity; and
- hydrogen chloride.

The opacity monitor should be equipped with visible and audible alarms at setpoints determined in consultation with the local jurisdiction. The hydrogen chloride monitor should be similarly configured and should be linked to the reagent feed system to provide automatic process control.

The hourly average data for opacity should be integrated from measurements taken every ten seconds.

4.8.4 Waste Feed Control. All facilities should be equipped with an automatic control system to inhibit waste feed to the incinerator whenever the operating parameters deviate from those specified in Sections 4.2, 4.3 and 4.4. In the case of temperature dropping below 1000°C, the control system should be capable of activating the auxiliary burner, followed by feed cut-off if the auxiliary burner fails to re-establish the required combustion temperature. The automated control system would be linked to all the continuous monitoring instruments necessary to enable performance of these functions.

4.8.5 Multiplex Arrangements. In a multiplex arrangement, where more than one unit is connected to one analyzer for a particular monitoring system, at least one five-minute average should be calculated based upon a continuous sampling period. The five-minute average is to be based on an uninterrupted five-minute period within a fifteen-minute segment. Multiplex arrangements should not be used for oxygen or temperature monitoring.

4.8.6 Accuracy. The gas sampling locations for the oxygen and carbon monoxide monitors should provide a representative sample of the gas stream. Stratification tests should be carried out to determine a suitable sampling location. The opacity monitor should be located at a point representing the stack opacity and calibrated as described in Environment Canada report EPS 1-AP-75-2 (2) using neutral density filters. The performance specifications of the monitoring system should be as follows:

- zero drift: less than 2% of full-scale span over a 24-hour period;
- calibration drift: less than 2% of full-scale span over a 24-hour period;
- linearity error: less than 2% of full-scale span;
- interference from other combustion gases: less than 2% of full-scale span at normal operating level; and
- response time: 3 minutes maximum.

5 OPERATING PROCEDURES

5.1 Start-up and Shutdown

5.1.1 Temperature. The minimum temperature of 1000°C specified in recommendation 4.2.1 should be attained using an auxiliary burner and control system before waste is introduced into the incinerator. This temperature must be maintained at all times during waste charging. During shutdown, the temperature should be maintained by operating the secondary burner:

- until the carbon monoxide level can be maintained below 50 ppmdv (57 mg/Rm^3) at 11% oxygen (this condition indicates the cessation of combustion on the grate);
- for a minimum of 15 minutes from the commencement of an unscheduled shutdown (not due to an electric power failure) requiring the use of any emergency discharge directly to the atmosphere; and
- until restoration of electrical power, or for at least one hour, whichever is the shorter period.

5.1.2 Waste Feed. The introduction of waste onto the grate of the incinerator should automatically cease in the event of an unscheduled shutdown.

5.1.3 Air Pollution Control System. The air pollution control system should not be bypassed during start-up and shutdown except in the following circumstances:

- when the gases from the system are below the specified temperature limit of the air pollution control system, i.e., to minimize the potential for condensation in the APC system; or
- where it is necessary to minimize the spread of a fire in the APC system; or
- in the event of induced draft fan failure where it is necessary to vent the equipment during emergency shutdown.

5.2 Upset Condition Responses

5.2.1 Emergency Shutdown. The automatic control system specified in recommendation 4.8.4 will cut off waste feed to the incinerator in the following upset conditions:

- oxygen concentration at the boiler outlet below the ranges specified in recommendation 4.2.6; or
- 4-hour average carbon monoxide concentrations greater than those specified in recommendation 4.2.8; or

- ignition of the auxiliary burner during operation of the incinerator failing to re-establish a fully mixed gas temperature of at least 1000°C.

Emergency shutdown is an ultimate measure; the process monitoring equipment should provide the incinerator operators with a warning of impending upset conditions. The following recommendations outline remedial actions that can be taken prior to curtailing feed to the incineration units.

5.2.2 Temperature. The control system should cope with the temperature variations associated with changing feed quality by adjusting the air or refuse feed levels to maintain the required temperature. Failure to maintain the temperature at the pre-set minimum will initiate auxiliary burner operation. Consistent low temperatures indicate a failure in the auxiliary burner or other system malfunction. In this case, the operator should check:

- burner controllers;
- air flow controllers;
- refuse feed system; and
- other anciliary equipment that could influence performance.

Air pollution control system efficiency is a function of operating temperature and several other variables, such as the reagent addition rate and residence time in the system. Elevated temperatures will lead to increased volatile metal emissions and, potentially, increases in trace organic emissions. Air pollution control system temperature should be regulated to ensure that the fabric filter bags are not damaged by excessively high temperatures. Temperature is controlled by the addition of water in either the gas conditioning system or as part of the lime slurry in the reactor. Since the removal of hydrogen chloride is partially a function of gas moisture levels, any failure of the water spray system could lead to both excessive temperatures and higher hydrogen chloride emissions. Minor variations in temperature should be expected, but consistently higher-than-normal temperatures or slowly increasing temperatures should prompt examination of the system. Failure of either the water supply or the air atomizing system associated with the conditioning tower will lead to increased temperatures. A drop in heat removal in the boiler could lead to increased thermal load to the conditioning tower and a potential increase in temperature through the system.

5.2.3 Carbon Monoxide. The carbon monoxide monitor provides an indication of combustion efficiency. Carbon monoxide concentrations in the flue gas will show some variability but in all cases the average values should be substantially below the standards recommended in Section 4.2. The operator should respond when carbon monoxide levels are twice the recommended four-hour rolling average.

The concentration of carbon monoxide can rise after a waste of particularly high energy content is charged to the incinerator. A temperature drop in the system can have the same effect. Any response to these variations must consider the factors that might influence the upset. Typical responses should comprise the following actions:

- check temperatures and oxygen levels on continuous monitoring systems to determine if they are normal;
- test the operation of the carbon monoxide monitor by performing zero and full-scale span checks;
- visually inspect the grates;
- check and adjust air distribution as necessary;
- reduce charging rate;
- manually start auxiliary burners; and
- shut down system.

Operators should be trained to recognize abnormal conditions during any of these checks and should be instructed to make the appropriate adjustments before moving to the next diagnostic stage. With sufficient intervention the operator should be capable of maintaining the rolling average in the recommended range without curtailing operation.

The oxygen and carbon monoxide monitors should be calibrated every 24 hours using pre-analyzed zero and calibration gas mixtures.

5.2.4 Opacity. Monitoring opacity in the stack provides an indication of possible fabric filter failures that might not be recognized until the system is tested using manual stack sampling techniques. Normally the opacity level will be less than 5% if the system is operating properly. Higher levels should prompt responses similar to those outlined for carbon monoxide, i.e., the following items should be checked:

- monitor performance;
- fabric filter pressure drops;
- fabric filter cleaning cycle time;
- system temperatures; and
- individual compartment operation.

The opacity monitor, used in its capacity as an early warning system, should provide the operator with enough time to rectify any potential operating problems.

5.2.5 Hydrogen Chloride. As previously indicated, the efficiency of the air pollution control system is a function of a number of conditions, including temperature and reagent addition rate. Outlet hydrogen chloride emission concentrations are a function of inlet concentrations which can vary from charge to charge and also depend on the time the charge has been burning. Responding to changes in hydrogen chloride concentrations, therefore, requires the operator to assess several factors. Compensating for some of the factors can take time and necessitate a longer averaging time for hydrogen chloride emissions.

To assess hydrogen chloride removal efficiency, the operator will require data from start-up and acceptance tests. The monitoring system should provide a means of sampling the uncontrolled hydrogen chloride level when required. High emission concentrations of hydrogen chloride should be subject to the following responses:

- check incinerator operation to ensure it is normal;
- check temperatures in the air pollution control system and operating conditions such as water and air pressure to ensure proper operation;
- test the hydrogen chloride instrumentation operation by performing zero and full-scale span checks;
- check reagent addition controller circuits and reagent addition rate;
- attempt to determine if failure is general (i.e., all incinerator/air pollution control lines or limited to one system);
- check waste composition to determine if there has been a major change;
- check inlet hydrogen chloride concentration to the control device to determine if "failure" is the result of refuse characteristic changes;
- attempt to rectify excessive emissions by:
  - increasing reagent addition rate;
  - reducing throughput; and, failing success,
  - shut down the unit.

As with any intervention due to abnormal operation, clearly document all findings and changes to assist future responses.

5.3 Spill Management

In any waste handling operation, the risk exists for unwanted releases and/or spills of substances that pose a potential hazard to human health and the environment. Therefore, a spill response plan should be developed for the incineration facility to adequately deal with spills and/or other discharges that may occur on site. The spill response plan should include the following information:

- monitoring and reporting procedures for all possible spills of materials;
- identification of all plant equipment and contents;
- a description of the hazards of materials that could be involved in potential spills;
- the chain of command designation during a spill incident;
- specification of equipment available for containment and cleanup procedures; and
- options available for the ultimate disposal of materials involved in a spill.

5.4 Operator Training

The owner of the waste incineration facility shall ensure that the operators of the facility have been properly trained to operate the facilities under normal and emergency situations. It is recommended that all operators receive training from a recognized program. Furthermore, it is recommended that Canada develop its own incinerator operator training program. In particular, operators should be trained in the following areas:

- the basic physical and mechanical features of the incineration facility;
- the function and location of the equipment within the facility including the control panel, and safety features of various control units;
- environmental concerns related to operation of the facility;
- emergency response procedures for hazardous wastes and other substances that may enter the facility including:
    - spill response procedures;
    - fire response procedures;
    - emergency and accident reporting requirements.

6 RECORDS AND REPORTING

6.1 Daily Inspections

The waste incineration facility should be inspected daily to detect leakage, spills, corrosion, hot spots, and malfunctions. The inspection should reveal whether gauges, recorders and monitors are functioning, if there are any signs of tampering with incinerator equipment and if repairs are required. The operator of the waste incineration facility should keep records of the inspections carried out. Such inspection reports shall include but not be limited to the following:

- the time and date of the inspection;
- the name and job title of the person carrying out the inspection;
- a description of the equipment inspected;
- the reason for the inspection;
- the observations made;
- any tests carried out and the results of the tests;
- a description of all equipment replaced and repairs and maintenance carried out as a result of every inspection; and
- the signature of the person making the inspection verifying that the information is correct.

6.2 Wastes

Throughout the operational life of the facility, daily records should be maintained and retained for the sources of incoming wastes; estimated quantities of incoming wastes, by weight; quantities and descriptions of outgoing wastes; and, quantities of waste burned.

6.3 Recording Devices

The original entry records for all recording devices should be retained throughout the operational life of the waste incineration facility.

6.4 Stack Testing

Stack testing should be conducted on the final discharge stack during normal operation of the waste incineration facility as follows:

- once, within six months of the start of full normal operation of the facility; and
- subsequently as required by provincial agencies.

The suggested minimum list of monitored parameters includes those listed in Table 4.2 of this guideline.– Local jurisdictions may require monitoring of additional contaminants and operating parameters.

6.5 Monthly Reports

Within 20 days following the end of each calendar month, a report should be prepared summarizing and commenting on the significance of the results from all recording devices, and daily waste and inspection records for the calendar month just ended. The report shall include the monthly averages for opacity, oxygen, hydrogen chloride and carbon monoxide as well as the following data:

- total hours of process operation;
- continuous emission monitoring system performance specifications and calibration data;
- percent availability of each monitor;
- percent sample recovery for the continuous emission monitors;
- total duration of:
    - stack opacity exceeding 5%,
    - carbon monoxide concentration exceeding the limits prescribed in recommendation 4.2.8,
    - combustion temperature below 1000°C,
    - fabric filter inlet temperature exceeding the acceptable range,
    - hydrogen chloride exceeding the rolling average values prescribed in recommendation 4.4.1;
- number of the above-mentioned conditions lasting more than 60 minutes or exceeding the recommended rolling average, and explanation for the condition;
- steps taken to remedy any upset conditions registered;
- relevant operating conditions during any discharge of flue gases by-passing pollution control equipment and the duration of such discharge; and
- operation of auxiliary burners.

Monthly reports should comply with all requirements of the jurisdiction. Copies should be provided to the appropriate provincial authority and should be made available to the public.

6.6 Annual Review

A performance review of the incineration facility should be conducted annually. The review should evaluate:

- overall plant performance;
- the adequacy of operation and maintenance standards;
- the output performance associated with the incineration of the wastes;
- housekeeping practices;
- occurrence of emergencies and the response measures taken;
- sources of wastes and estimated quantity by weight;
- the quantities and description of any outgoing waste;
- details of downtime of the incinerator, together with related causes; and
- frequency, duration and cause of each pollution control system bypass.

The complete annual report shall be given to appropriate provincial authority and should be made available for review by interested members of the public.

REFERENCES

1) Environment Canada, The National Incinerator Testing and Evaluation Program : Air Pollution Control Technology. Report No. EPS 3/UP/2, Ottawa, 1986.

2) Environment Canada, Standard Reference Methods for Source Testing: Measurement of Opacity of Emissions from Stationary Sources, Report EPS 1-AP-75-2, Ottawa, 1977.

APPENDIX A

Emission Data Conversion

APPENDIX A: EMISSION DATA CONVERSION

The units used for reporting air emission levels vary widely, as do the reference conditions for reporting these emissions. These recommendations have adopted the following convention.

Standard Conditions

In order to standardize the composition of the gas and associated concentrations of the contaminants, the emission objectives in the guidelines are expressed in relation to dry cubic metres of flue gas at 25°C and 101.3 kPa (atmospheric pressure). Therefore, concentrations of contaminants in this document are expressed as:

"x" mass/Rm^3

where R refers to the above flue gas reference conditions. When considerating gas concentration data in parts per million dry volume (ppmdv) the gas is considered to be at the same reference conditions.

In addition to reference temperature and pressure conditions, the degree of dilution air in the gas stream is defined as 11% (by volume) of oxygen, designated as 11% O_2. In most incineration systems at typical excess air levels 11% oxygen is close to the level achieved.

Conversion

For convenience the conversion of gaseous emission concentrations from units of parts per million dry flue gas (ppmdv) as measured by stack sampling to the mass concentration units will be accomplished using the perfect gas law in the form of the following equation:

$$\underset{(mg/m^3)}{\text{Concentration}} = \underset{(ppmdv)}{\text{Concentration}} \times \frac{(0.04087 \times M\ P\ T_R)}{P_R\ T} \quad (1)$$

where:

M	=	molecular weight of pollutant in gram moles
P	=	pressure (in kPa) of analyzer
P_R	=	atmospheric pressure in kPa (101.3 kPa)
T	=	temperature at analyzer in K = °C + 273.15
T_R	=	reference temperature 298.15 K (25°C)

Molecular weights for typical flue gas constituents in gram moles are:

CO_2	Carbon Dioxide	44.01
CO	Carbon Monoxide	28.01
HCl	Hydrogen Chloride	36.47
CH_4	Methane	16.04
NO_x as NO_2	Oxides of Nitrogen	46.01
NO	Nitric Oxide	30.01
SO_2	Sulphur Dioxide	64.07

Conversion of data to the 11% oxygen basis from another basis is accomplished using the following equation:

$$\text{Concentration}_{(\text{at 11\% } O_2)} = \text{Concentration}_{(\text{at reference conditions, REF})} \times (20.9 - 11.0)/(20.9 - O_{2REF}) \quad (2)$$

where: O_{2REF} = $20.9 - 1.14\ CO_2(\%)$ dry, or,

= (20.9% excess air (EA)) /(100% + % EA), or,

= another level of O_2 (%)

$\text{Concentration}_{REF}$ = concentration of contaminant reported at the other reference condition

If the temperature is different in the reported concentration unit, then the concentration unit has to be adjusted for temperature by taking the ratio of the absolute temperatures (i.e., the ratio of the absolute reported temperature to the absolute temperature at the reference conditions (25°C), T/T_R.)

Examples:

In Denmark, the emission standard for hydrogen chloride is given as 100 mg/Nm^3 at 10% oxygen which by definition is at 0°C. In order to convert this to the reference conditions given in this report, the first step is to perform the conversion to 11% oxygen.

$$\frac{20.9 - 11}{20.9 - 10} \times 100 \text{ mg/Nm}^3 = 91 \text{ mg/Nm}^3$$

The second step involves converting the concentration to the reference temperature of 25°C.

$$91 \times T/T_R = 91 \times 273.15/298.15 = 83 \text{ mg/Rm}^3 \text{ @ } 11\% \text{ O}_2 \text{ (mg/Nm}^3\text{)}$$

Similarly the Swedish standard is 100 mg/Nm^3 at 10% carbon dioxide which must first be converted to the reference condition of 11% oxygen and then to the reference temperature conditions. This can be done in one step using the combination of the procedures previously outlined.

$$100 \times (20.9\text{-}11.0)/[20.9\text{-}(20.9\text{-}1.14\text{x}10)] \times 273.15/298.15 = 80 \text{ mg/Rm}^3 \text{ @ } 11\% \text{ O}_2$$

In this case, the carbon dioxide basis must be changed to the oxygen reference condition using equation (2).

APPENDIX B

Toxicity Equivalency Factors

APPENDIX B
TOXICITY EQUIVALENCY FACTORS (TEFs) FOR SPECIFIC PCDD AND PCDF CONGENERS

When only homologue test data is available apply the largest equivalency factor

Homologue	Positions Chlorinated	Equivalency Factor
T_4CDD	2,3,7,8	1
P_5CDD	1,2,3,7,8	0.5
H_6CDD	1,2,3,4,7,8	0.1
	1,2,3,6,7,8	0.1
	1,2,3,7,8,9	0.1
H_7CDD	1,2,3,4,6,7,8	0.01
O_8CDD	1,2,3,4,6,7,8,9	0.001
T_4CDF	2,3,7,8	0.1
P_5CDF	1,2,3,7,8	0.05
	2,3,4,7,8	0.5
H_6CDF	1,2,3,4,7,8	0.1
	1,2,3,7,8,9	0.1
	1,2,3,6,7,8	0.1
	2,3,4,6,7,8	0.1
H_7CDF	1,2,3,4,6,7,8	0.01
	1,2,3,4,7,8,9	0.01
O_8CDF	1,2,3,4,6,7,8,9	0.001