1.0 Introduction

1.1 Purpose

This *Technical Document for Batch Waste Incineration* was developed to provide guidance for owners and operators of batch waste incinerators regarding proper system selection, operation, maintenance and record keeping, with the goals of assisting them in achieving the intent of the Canada-wide Standards (CWS) for dioxins/furans and mercury, and reducing releases of other toxic substances. This technical document focuses on batch waste incinerators ranging in size from 50 to 3,000 kg of waste/batch. Batch waste incinerators are those that operate in a non-continuous manner (i.e. they are charged with waste prior to the initiation of the burn cycle, and the door remains closed until the ash has cooled inside the primary chamber). Air emission testing completed by Environment Canada in 2002 using a modern Canadian-built batch waste incinerator revealed that, when properly operated and maintained, these systems are capable of meeting the CWS for dioxins/furans (80 pg I-TEQ/Rm^3 @ 11% O_2) and mercury. Stack testing can be carried out as required by the regulatory authorities in order to verify that these standards are met.

The document includes:

- A discussion on the importance of reducing, reusing and recycling to divert wastes from disposal;
- Methods for the selection of appropriate incineration technologies to meet specific waste management requirements;
- Operational requirements that should allow batch waste incinerators to meet the intent of the CWS for dioxins/furans and mercury, and to reduce the release of other toxic substances; and
- Recommendations on record keeping and reporting.

Owners and operators are advised to undertake a full review of relevant local legislation and consult with the appropriate regulators before proceeding with any waste management operation.

1.2 Background

Incineration is recognized as an effective and environmentally sound disposal method for a wide range of wastes, and is used in facilities and jurisdictions across Canada. Waste generators located in remote areas may have limited options for cost-effective and environmentally sound waste management, and incineration may therefore be considered an appropriate waste management option. Remote commercial activities, such as exploration and development of natural resources, can create large volumes and varieties of wastes that must be managed appropriately. Residual wastes from industry, research activities, and the health care sector may require thermal treatment as an environmentally sound method to control the spread of disease from plants, animals or humans. Furthermore, there are certain locations in Canada where incinerating waste is an important means of avoiding potentially dangerous interactions between humans and wildlife. In all cases, reduction and diversion should be the primary waste management objectives, prior to considering any disposal option.

This section provides background information on batch waste incineration, including: substances of concern; international and national initiatives; and provincial/territorial initiatives.

1.2.1 Substances of Concern

There are some important potential environmental concerns associated with waste incineration that can be addressed through proper equipment selection, operation, maintenance and record keeping. These include potential releases of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/F), which are persistent organic pollutants (POPs), and mercury.

Dioxins and Furans

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDD/F), commonly known as dioxins/furans (D/F), are toxic, persistent, bioaccumulative, and result predominantly from human activity.

Data from the measurement of dioxins/furans in the North shows that these chemicals are frequently found at concentrations far in excess of those that might be explained by local production. With the increased social and economic development in Canada's North, it is important to control these persistent chemicals.

Dioxins and furans can be generated from incomplete combustion resulting from the use of inadequate technology and/or operating the incinerator improperly.

Mercury

Another possible contaminant released from incinerators is mercury. Mercury bio-accumulates in the environment and, like POPs, is found in polar regions at higher concentrations than can be explained by local anthropogenic releases.

Mercury is not emitted from the incinerator unless items containing mercury are placed into the incinerator. The best method to control mercury releases is therefore to limit the amount of mercury in the waste fed to the incinerator.

1.2.2 International and National Initiatives

Over the years, Canada has participated in numerous initiatives to reduce dioxins and furans as well as mercury releases such as:

- Stockholm Convention on Persistent Organic Pollutants;
- CCME Policy for Management of Toxic Substances;
- Federal Toxics Substances Management Policy (TSMP),
- Canada Wide Standards for Dioxins and Furans;
- Canada Wide Standards for Mercury; and,
- Chemicals Management Plan.

Stockholm Convention on Persistent Organic Pollutants

Canada is a Party to the Stockholm Convention on Persistent Organic Pollutants (POPs), which entered into force in May 2004. The Stockholm Convention sets out a range of measures to reduce and, where feasible, eliminate POP releases[2].

Incineration was identified as a potential source of the POPs listed in Article 5 of the Stockholm Convention. Article 5 of the Convention requires Parties to take measures to reduce, and where feasible, eliminate releases of unintentionally produced POPs, including dioxins, furans, hexachlorobenzene (HCB) and dioxin-like polychlorinated biphenyls (PCBs) which are "*unintentionally formed and released from thermal processes involving organic matter and chlorine as a result of incomplete combustion or chemical reactions*".

Article 5 also requires that Best Available Techniques (BAT) and Best Environmental Practices (BEP) be applied for both new and substantially modified sources. "Best Available Techniques" are defined as using the most effective and advanced techniques that can be practically adopted to:

- *prevent or minimize* harmful emissions of by-product POPs and other environmental impacts; or,
- *reduce* by-product POPs releases to acceptable limits.

"Best Available Techniques" techniques can be applied by an operator to a specific facility since they have been developed to a state that they are economical and technically viable. Similarly, "best environmental practices" implies the application of the most appropriate combination of environmental control measures and strategies. Annex C states that for the purposes of the Convention there are a series of measures that are appropriate:

> *"Improvements in waste management with the aim of the cessation of open and other uncontrolled burning of wastes, including the burning of landfill sites. When considering proposals to construct new waste disposal facilities, consideration should be given to alternatives such as activities to minimize the generation of municipal and medical waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste."*

CCME Policy for Management of Toxic Substances and the Federal Toxics Substances Management Policy

Canada took steps to improve the management of POPs even before the Stockholm Convention was adopted. Polychlorinated dioxins-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) were designated as Track 1 substances and scheduled for virtual elimination from the Canadian environment under the 1995 federal *Toxic Substances Management Policy* [3] and the 1998 CCME *Policy for the Management of Toxic Substances*[4].

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2 At the Conference of Plenipotentiaries on the Stockholm Convention on Persistent Organic Pollutants, held May 22 to 23 2001 in Stockholm, Sweden, the Convention was adopted and opened for Signature. It remained open for signature at the United Nations Headquarters, Treaty Section, in New York, until May 22, 2002. Available on-line at: http://chm.pops.int/

3 Environment Canada, Toxic Substances Management Policy. 1995. Available at http://www.ec.gc.ca/toxics/TSMP/en/tsmp.pdf

4 CCME. 1998. CCME Policy for the Management of Toxics Substances. January 29, 1998. Available at http://www.ccme.ca/assets/pdf/toxics_policy_e.pdf

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PCDD/F are on the List of Toxic Substances in Schedule 1 of the *Canadian Environmental Protection Act, 1999*[5].

Under the federal 1995 *Toxic Substances Management Policy* and the 1998 *CCME Policy for Management of Toxic Substances*, mercury was designated as a Track 2 substance. As such, mercury must be managed through its life cycle to minimize releases. Mercury is on the List of Toxic Substances in Schedule 1 of the *Canadian Environmental Protection Act* (CEPA 1999).

Canada-wide Standards for Dioxins and Furans

The Canadian Council of Ministers of the Environment (CCME) examined the incidental release of dioxins and furans in emissions from various combustion systems. This led to the development of the *Canada-wide Standards for Dioxins and Furans*, which were adopted by the CCME in 2001. The standards identify incineration for action to reduce emissions, and include specific air emission standards.

In a 2007 review of the Dioxins and Furans Canada-wide Standards for waste incineration[6], a series of recommendations were made by the Dioxins and Furans Incineration Canada-wide Standards Review Group regarding batch incinerators in remote locations. These recommendations suggest that:

- The company/department should take appropriate measures to ensure good operation and provide adequate records of such operation;
- The company/department should only use incinerators that are equipped with monitoring equipment (temperature probes, differential pressure meters and auxiliary fuel flow) to ensure that proper operation is maintained. The monitoring equipment should be connected to a computer which will continuously log the data recorded;
- All installations should install weigh scales to record the weight of each load charged to the incinerator;
- All data from these systems should be available to inspectors;
- The computerized data acquisition equipment should be integrated with all the operating controls of the incinerator in a manner that would facilitate remote access to the data to enable the manufacturer to assist the operator with trouble shooting the operation;
- Operators should be trained, either through an appropriate site specific training program or through a certification program provided by a qualified body;
- Operators should be instructed to distinguish between broad categories of waste, in terms of their calorific value, and be given clear instructions on how much from each category is suitable for charging to the primary chamber for a given batch;
- All facilities should be required to file, with the appropriate regulatory authority, their annual waste throughput data. This filing should include details on the quantity and disposition of residues discharged from the facility.

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5 CEPA, 1999. Canadian Environmental Protection Act, 1999. 1999, c. 33 (Assented to September 14, 1999). Available at http://www.ccme.ca/assets/pdf/mercury_emis_std_e1.pdf

6 Chandler, A.J., 2007. Review of Dioxins and Furans from Incineration In Support of a Canada-wide Standard Review: A Report Prepared for The Dioxins and Furans Incineration Review Group through a contract associated with CCME Project #390-2007. Available at: http://www.ccme.ca/assets/pdf/1395_d_f_review_chandler_e.pdf

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Canada-wide Standards for Mercury

The Canada Wide Standards for Mercury Emissions were adopted in 2000 in order to reduce atmospheric emissions derived from both deliberate use of mercury and from incidental releases of mercury[7]. The standards include limits for mercury emissions from waste incinerators.

The Mercury Containing Product Stewardship: Manual for Federal Facilities[8] provides useful information on how to develop an inventory of mercury within a facility, reducing mercury through life-cycle management practices, and monitoring and reporting on mercury stewardship activities.

Chemicals Management Plan

Canada's efforts to improve the environment have also led to new measures under the Chemicals Management Plan (CMP)[9], which was first brought forward in 2006. The CMP develops measures to better protect human health and the environment from the risks posed by chemical substances. Since CEPA was adopted, all new chemicals have received rigorous pre-market assessments; however, approximately 23,000 "legacy" chemicals were in use in Canada before CEPA came into effect. The CMP identified a list of 193 substances as priority for action. Industry is required to provide Environment Canada and Health Canada with information regarding these substances on a quarterly basis within the next three years. The information that is received, along with that gathered from other sources, will be assessed and used to decide, if necessary, the appropriate actions required to protect the health of Canadians and the environment.

The Waste Sector has been identified as a sector under the CMP due to potential releases to the environment from incinerators and landfills.

1.2.3 Provincial / Territorial Initiatives

The CWS for both dioxins/furans and mercury have been incorporated into regulations related to new incinerators in various provinces. One example is the Ontario Guideline A-7[10] which incorporated the CWS emission values for new incinerators shortly after they were adopted and Guideline A-7[11] which clarified the approach for existing facilities in 2004. In many cases, the adoption of the CWS by provincial regulators has resulted in the closure of older incineration facilities. Some facilities have been upgraded to meet the new standards.

Canadian Council of Ministers of the Environment (CCME). Canada-wide Standard for Mercury Emissions, 2000. Available at: http://www.ccme.ca/ourwork/air.html?category_id=87

Mercury-containing Product Stewardship: Manual for Federal Facilities. (2004). Environment Canada. Available at http://www.ec.gc.ca/Mercury/ffmis-simif/Manual/index.aspx?lang=E

Chemicals Management Plan (CMP). 2006 Notice of intent to develop and implement measures to assess and manage the risks posed by certain substances to the health of Canadians and their environment. Under the *Canadian Environmental Protection Act*, 1999. http://www.chemicalsubstanceschimiques.gc.ca/en/index.html

Ontario Ministry of the Environment, 2004. GUIDELINE A-7 Combustion and Air Pollution Control Requirements for New Municipal Waste Incinerators. Legislative Authority: *Environmental Protection Act*, Part V, Section 27, and Part II, Section 9. Last revision February, 2004. Available at: http://www.ene.gov.on.ca/envision/gp/1746e.pdf

Ontario Ministry of the Environment, 2004. GUIDELINE A-8 Guideline for the Implementation of Canada-wide Standards for Emissions of Mercury and of Dioxins and Furans and Monitoring and Reporting Requirements for Municipal Waste Incinerators Biomedical Waste Incinerators Sewage Sludge Incinerators Hazardous Waste Incinerators Steel Manufacturing Electric Arc Furnaces Iron Sintering Plants. Legislative Authority: *Environmental Protection Act*, Part V, Section 27, and Part II, Section 9, August 19, 2004. Available at: http://www.ene.gov.on.ca/envision/gp/4450e.pdf

2.0 The Waste Incineration Process

This section provides background information on the waste incineration process in order to provide a basis for understanding the recommendations contained later in the report. This chapter discusses: controlling combustion and emissions; waste incineration technologies; and, general design and operation considerations.

2.1 Controlling Combustion

2.1.1 Overview of the Waste Incineration Process

Gases, liquids and solids containing carbon and hydrogen can be burned. The way each state of matter burns is different. In the context of this document, waste being incinerated is mostly in solid form as opposed to a liquid or a gas.

Most solid fuels contain both volatile materials and fixed carbon. During combustion, two different processes occur: the gaseous volatile materials are released and oxidised; and, the fixed carbon is oxidised.

In the first process, the volatile materials are released by pyrolysis reactions that convert the waste into gases consisting of hydrogen, carbon monoxide (CO), light hydrocarbons and tars. Once released in the high temperature environment, the hydrogen reacts instantaneously with oxygen to form water vapour. The CO oxidises to form carbon dioxide (CO_2) at a slightly slower rate. The hydrocarbons and tars react to form hydrogen and carbon, which in turn are oxidised. The gaseous reactions require oxygen and an elevated temperature. If the gases and the air are not well mixed some of the reactions do not go to completion and tars and other products of incomplete combustion, such as dioxins/furans, can also be released to the flue. Under these circumstances, the stack gases will be cooler and tars and other products of incomplete combustion will condense on the flue walls as soot or tar deposits.

In the second process, the remaining fixed carbon oxidizes and releases CO. This reaction takes longer than the release of the volatile materials because oxygen must diffuse to the material's surface where it can react. The rate of this reaction is proportional to the exposed surface area available.

Throughout the combustion process, the oxidation of CO to CO_2 occurs through reactions with hydroxyl (OH) radicals. If excessive air is present in the combustion zone, the combustion temperature and the concentration of hydroxyl radicals will be reduced and the CO oxidation reaction will be inhibited. This results in elevated concentrations of CO in the exhaust gases. Insufficient air can also lead to high CO concentration because there will be insufficient oxygen to oxidise the CO.

The burning of waste in an incinerator is essentially a rapid oxidation process that generates heat and converts the waste to the gaseous products of combustion, namely carbon dioxide and water vapour, which are released to the atmosphere. At the end of the burning process, there may be residual materials and ash that cannot burn.

2.1.2 Controlling Combustion

Controlling combustion during the waste incineration process is very important for in order to minimize the formation and release of products of incomplete combustion such as dioxins and furans. The intent is to ensure that the combustion process is as complete as possible, yielding residues with little carbon, and stack gases containing only carbon dioxide and water vapour.

Solid waste is generally characterized as heterogeneous, with materials that burn at different rates. The rate of burning is determined by the amount of air added to the waste. When burning waste in a well designed incinerator, air flows are controlled to ensure high temperatures and a clean burn.

Burning is an oxidation reaction that requires a precise amount of oxygen to mix with the material being burned. This is termed the stoichiometric oxygen requirement. There must be just enough oxygen molecules to combine with the carbon and hydrogen from the waste to create carbon dioxide and water. If the quantity of oxygen available is just enough, the temperature generated by the reactions will reach its maximum. If too little or too much oxygen is present, the temperature achieved in the system will be lower.

In batch incinerators, the waste sits stationary on a solid surface referred to as the hearth. The heterogeneous mix of waste on the hearth changes as the waste is reduced to ash through gasification and oxidation reactions. The initial heat required to ignite the waste is supplied by a burner that uses propane, natural gas or oil. Since the fuel supply to the burner is continuous, the burner can stay on indefinitely during the burn cycle. However, this would increase operating costs, and so the incinerator controls shut off the burner once the waste on the hearth has generated sufficient heat to allow the reactions to become self sustaining.

Air must be provided to sustain the combustion process. In batch incinerators, the air is supplied through holes in the incinerator walls. These holes are positioned so that the air is directed to the base of the hearth. In larger continuously operated incinerators, these air ports are under the fuel bed. In either case the air introduced in this manner is termed “under fired” air to denote where it is injected. Air must also be added above the hearth to burn the gases generated. This air also enters through air ports, and is referred to as “over fired” air. In dual chamber incinerators the over fired air is added in the secondary chamber. It is not sufficient just to add the over fired air, it must be well mixed with the volatile gases to ensure good combustion. This mixing is typically accomplished by passing the volatile gases through a “flame port” that is smaller than the primary chamber dimensions. Air can be added in the flame port or immediately after it. The flame port increases the gas velocity and introduces turbulence into the gas stream to promote mixing.

The oxidation reactions require a finite amount of time for completion, meaning that the duration of exposure at elevated temperatures must be controlled. Since batch incinerators typically lack any mechanism for agitating the waste, the temperature in the system must be maintained by re-igniting the primary burner. The combustion cycle for a batch waste incinerator is thus set to ensure maximum carbon reduction of the waste on the hearth.

The type of waste incinerated can have significant implications for the control of combustion. Paper and plastics have a higher energy value and require more air to complete the combustion process. Food wastes, with lower energy levels, require less air to complete the burning process. However, the moisture in food waste has to be evaporated before the carbon can sustain combustion. Thus, food wastes must be heated for longer periods before the combustion process commences and the primary burner can be shut off.

Combustion in the secondary chamber of a dual chamber incinerator will respond to the quantity of volatile gases present. As the volatile gas release rate drops, the temperature in the secondary chamber will also drop. To address this issue, most batch waste incinerators are equipped with secondary chamber auxiliary fuel burners. These burners maintain the desired temperature in the secondary chamber and assist with heating the incinerator during start up. The secondary chamber is typically sized to provide the gases with a one second residence time at 1000^{O}C.

2.1.3 Reducing Dioxin and Furan Emissions

Emissions of air contaminants from batch waste incinerators are a function of the design and operation of the equipment, and the nature of the materials being processed. Heavy metals present in the waste will be released with the exhaust gases. If there is mercury in the waste, mercury will be found in the emissions. If no mercury enters the incinerator, it cannot exit the stack. However, the same approach cannot be used to reduce the emissions of POPs, and in particular, dioxins and furans (PCDD/F).

It is known that at temperatures in excess of 600^{O}C, any PCDD/F will be destroyed. However, even in incinerators with good combustion there is a potential for PCDD/F formation due to *de novo* synthesis reactions. *De novo* reactions occur at temperatures in the 250 - 450^{O}C range when stack gases and fly ash are in contact for periods exceeding a few seconds. It has been postulated that residual carbon in the fly ash reacts with components in the exhaust gases to form PCDD/F. Given this behaviour, it should not be surprising that facilities with low temperatures have been identified as those having higher PCDD/F emissions.

Chemical reactions are driven by concentration gradients, so the higher the concentrations of carbon and fly ash the more likely the reaction will produce high emissions. Similarly, incinerators with higher concentrations of fly ash in zones with lower temperatures are anticipated to produce significantly more *de novo* reactions.

Carbon monoxyde (CO) concentrations in the exhaust gases are a good indicator of combustion efficiency. Most incinerators can be adjusted to give a minimum CO concentration. For batch waste incinerators, CO concentrations should be below 50ppm. If the incinerator is not operated appropriately (for instance, if the waste has a high calorific value and insufficient air is provided to complete the combustion process), CO levels will rise and black smoke will be released. Such smoke will contain large quantities of carbon that can react to produce higher PCDD/F emissions. Conversely, if the waste cannot create enough heat in the primary chamber to achieve the target temperatures, perhaps because too much air is leaking into the incinerator, there will be zones in the incinerator where temperatures could be in the *de novo* reaction range. The extra air can also entrain particulate matter from the hearth raising fly ash levels in the gas stream. The result will be higher PCDD/F concentrations than might be found in a properly operating system.

2.2 Waste Incineration Technologies

A waste incinerator is a system constructed to thermally treat (i.e. combust or pyrolyze) a waste for the purpose of reducing its volume, destroying a hazardous substances or pathogens present in the waste. There are two main types of waste incinerators: batch and continuous. Batch waste incinerators are loaded with waste through an open door which is then closed before the waste is ignited. The door remains closed until the ash residues remaining on the hearth have cooled and can be safely removed. The duration of a batch waste incinerator cycle is measured in hours. In comparison, continuously operated incinerators receive fresh waste and discharge ash residues periodically throughout their operation, which can last from weeks to months. This Technical Document focuses on minimizing dioxins/furans and mercury emissions from batch waste incinerator systems ranging in size from 50 to 3,000 kg of waste/batch.

For facilities incinerating more than 26 tonnes of waste per year (tpy), the preferred incinerator for new installations is the dual chamber controlled air incinerator. The dual chamber controlled air incinerator has two chambers and each chamber is equipped with air ports that allow the quantity of air added in various parts of the incinerator to be controlled. They are capable of achieving the higher operating temperatures required to minimize the emissions of POPs, and particularly dioxins/furans. Figures 2.2 and 2.3 illustrate the design of a typical dual chamber controlled air incinerator.

Batch waste incinerators have a zone where the waste is ignited and mixed with air to promote combustion, and a second zone where additional air is added to complete the combustion process. In large continuously operated incinerators, the energy available in the hot exhaust gas stream may be recovered in a heat recovery steam generator (HRSG) or hot water boiler. The steam generated can be used to produce electricity or it can be used for process or space heating. Heat recovery is not recommended for batch waste incinerators, as it lowers the gas temperatures in the system and can lead to *de novo* synthesis formation of PCDD/Fs.

Large continuously operated incinerators are equipped with air pollution control (APC) systems to treat the hot gases leaving the heat recovery system. The gases leaving the heat recovery system are cooled by a fine water mist to reduce the size of the required air pollution control equipment and to protect the incinerator from high gas temperatures. If a large continuously operated incinerator is not equipped with a heat recovery system, a rapid water quench system is used to achieve the desired gas temperatures. Such quenching will limit the potential for *de novo* synthesis of PCDD/Fs because the gases do not remain in the critical temperature range for sufficient time to allow the *de novo* reactions to proceed.

APC systems are not recommended for batch waste incineration systems to control PCDD/F emissions. Stack gases should be released directly to the atmosphere at temperatures in excess of 700^{O}C to reduce the chances of inadvertent formation of PCDD/F through the *de novo* synthesis process.

After the waste has been oxidized in the primary chamber, residues, generally referred to as bottom ash, must be removed. Bottom ash from well-operated incinerators has been shown to contain low PCDD/F concentrations (<20 pg TEQ/g of bottom ash). Solid residues deposited in the heat recovery system of large continuously operated incinerators typically have <50 pg TEQ/g of PCDD/F whereas residues from air pollution control systems typically have <300 pg TEQ/g of PCDD/F. The deposits from heat recovery systems and air pollution control systems are generally referred to as fly ash because the ash has travelled suspended in the exhaust gases. Because of low gas velocities, batch waste incinerators create much less fly ash than large continuously operated incinerators.

Figure 2.2 Typical Controlled Air Dual Chamber Incinerator

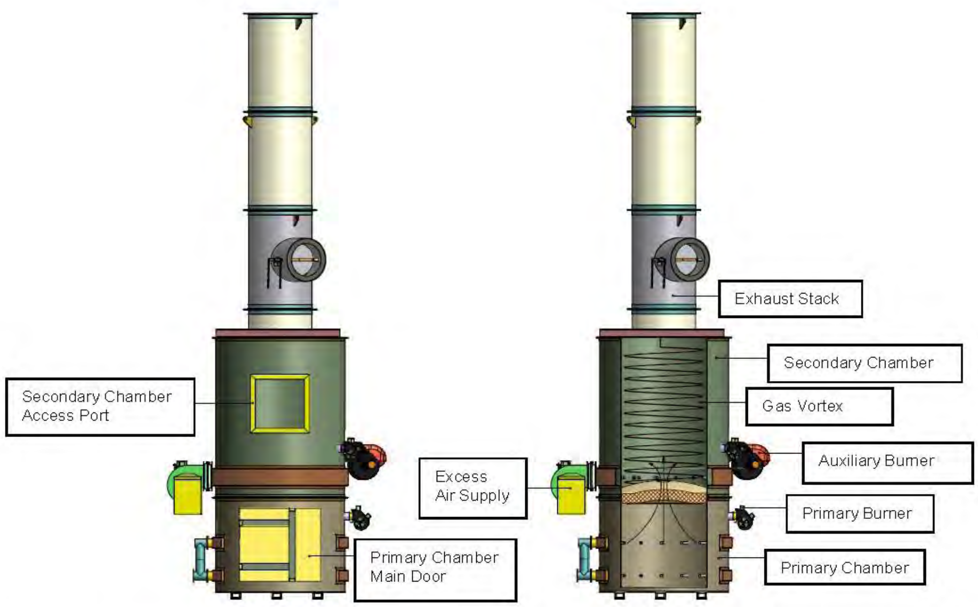

Figure 2.3 Schematic of Typical Controlled Air Dual Chamber Incinerator

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2.3 General Design and Operation Considerations

2.3.1 Design and Operation

The design features addressed below are deemed to be most important for those contemplating buying a dual chamber controlled air batch incineration system. As mentioned previously, the emphasis is on batch waste incinerators that are capable of disposing of up to 3,000 kg of waste per batch.

The degree to which the combustion process is completed is a function of:

- the temperature the combusting gases reach;
- the length of time the gases remain at elevated temperatures;
- how well the air and the gases are mixed; and
- whether there is adequate oxygen to permit complete combustion.

Combustion temperatures downstream of the primary chamber and the residence time for gases at this temperature are frequently specified in regulations. In Ontario, for example, waste incinerators must provide a 1 second residence time for gases at 1,000^{O}C[12]. In the European Union, the requirements are two seconds at 850^{O}C[13]. These values reflect operating conditions in incinerators with low emissions.

The incinerator designer has more discretion in defining the temperatures in the primary chamber. Primary chambers are designed with consideration of the wastes that will be destroyed. Materials that are harder to burn require higher operating temperatures. The design temperature is governed by the rate at which heat is released in the primary chamber, which is known as the target volumetric heat release rate and expressed in MJ/m^3/hour. This value is based upon the calorific value of the waste in MJ/kg, the quantity of waste to be charged to the incinerator in kg/batch, and the volume of the primary chamber in cubic metres. The operating temperature in a system provides a limit for the volumetric heat release rate. For the typical dual chamber incinerator, the primary chamber should operate in the 500 – 800^{O}C range.

Since the temperatures achieved in a specific primary chamber are a function of the heat release rate and the waste mass, it is important that the incinerator be loaded with waste that matches its particular design characteristics. It should be remembered that by design, incinerators are heat release limited devices. Too little heat and the material will not burn properly; too much heat will lead to damage to the incinerator. When the appropriate amount of energy is introduced into the primary chamber, the primary chamber temperature in a batch waste incinerator can be controlled principally through adjusting the air to fuel ratio.

Air addition to the primary and secondary chambers of batch waste incinerators will result in exhaust oxygen concentrations in the range of 6 – 12%. Operation in this zone will minimize the release of CO and thus also minimize trace organic releases. This range can be reduced based upon testing of a given system to produce minimum CO levels. Maintaining oxygen

12 Ontario Ministry of the Environment, 2004. GUIDELINE A-7 Combustion and Air Pollution Control Requirements for New Municipal Solid Waste Incinerators.

13 Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste. 2000.

concentrations within the manufacturer's recommended range will ensure that the system is operating at in the most efficient manner.

As noted, temperature control involves regulating the air to fuel ratio. To lower the temperature, more air is added, up to the maximum flow. Alternatively the auxiliary fuel flow rate can be reduced. The primary chamber of a batch waste incinerator is designed for a waste mass of a certain calorific value. The air supply system is sized to provide the appropriate level of excess air to control the temperature to the desired level, even if the heat input varies from design.

It is considered poor practice to introduce wastes at either extreme of the calorific value range if good combustion is the objective. In order to prevent any situation where the temperature might be damaging to the primary chamber, the quantity of high calorific waste in any charge must be limited. Wastes should be mixed to achieve a relatively uniform heating value close to the design point of the unit. If the operator controls the quality of the waste mix, any variability in the rate that the waste burns can usually be managed by the control systems of the incinerator.

2.3.2 Heat Recovery

In most cases, batch waste incinerators should not be equipped with heat recovery because this can lower temperatures and lead to *de novo* synthesis formation of PCDD/Fs.

2.3.3 Air Pollution Control Systems

Air Pollution Control (APC) systems with evaporative cooling towers and dry scrubbers are seldom recommended for small batch fed incinerators for two main reasons:

- Due to the non-continuous nature of batch waste incineration, gas temperatures will vary from ambient to operating levels as high as 1,200^{O}C each time the system is operated. When not at high temperature, condensation can occur and cause corrosion in the system. Furthermore, deposits remaining in the duct work during the cool down phase pass through the *de novo* synthesis temperature and can increase the production of PCDD/Fs.
- Since the non-continuous nature of batch waste incinerator operation generally makes it impractical to install a heat recovery system, there will be no initial cooling of the gas stream and higher temperatures will enter the APC system. To prevent equipment damage, some means of rapid gas cooling would need to be installed. This would require large volumes of water, some of which will collect hydrochloric acid and other acidic gases, and would require treatment or at the least re-circulation in the system. In certain areas of the country, obtaining the water and treating it could present significant challenges.

Adding an APC system to a batch waste incinerator will also increase the pressure drop across the system. This will result in the need for induced draft fans to exhaust the combustion gases. The induced draft fan and the air pollution control system will increase the energy requirements of the incinerator.

In most cases, APC systems are not recommended for batch incineration systems to control

PCDD/F emissions. By ensuring good combustion control and exhaust gas temperatures in excess of 700^{O}C, there should be little opportunity for the formation of PCDD/F through *de novo* synthesis

However, in certain jurisdictions and/or operating conditions it may be necessary to employ an APC system. Owners and operators should consult with manufacturers and local regulatory authorities regarding any such requirements.

3.0 The Six-Step Process for Batch Waste Incineration

The recommended Six-Step Process for Batch Waste Incineration includes:

Step 1 – Understand Your Waste Stream

Step 2 – Select the Appropriate Incinerator (or Evaluate the Existing System)

Step 3 – Properly Equip and Install the Incinerator

Step 4 – Operate the Incinerator for Optimum Combustion

Step 5 – Safely Handle and Dispose of Incinerator Residues

Step 6 – Maintain Records and Report

The Six-Step Process will assist owners and operators of batch waste incinerators, ranging from 50 to 3,000 kg/batch, in achieving the intent of the CWS for dioxins/furans and mercury, and reducing the potential for releases of other toxic substances to the environment.

3.1 Step 1: Understand Your Waste Stream

The first step in managing waste is to understand the quantity and composition of the waste that is generated. A waste audit should be completed, where practical, to:

- Determine the quantity of waste generated in the various parts of an operation;
- Characterize the waste from each type of operation;
- Examine the waste stream to determine what opportunities exist for:
    - Reducing the quantity of waste generated;
    - Reusing materials; and
    - Recycling as much as possible before considering disposal.

Where waste audits are not practical, it is still necessary to develop an estimate of the waste quantities and characteristics before a strategy for waste diversion and disposal can be completed. Owners should investigate waste generation and diversion data from similar operations/facilities in order to estimate the waste types and quantities that will be generated at their own facilities. Sources of such information may include industry associations, waste industry consultants, provincial/territorial authorities and other regulatory bodies.

Based on the results of the waste audit/characterization, an assessment of appropriate disposal options should be undertaken. Where possible, disposal alternatives (other than incineration) for the residual waste stream (i.e. post 3Rs – Reduce, Reuse, Recycle) should be examined. When assessing disposal options, it is important to note that waste should neither be open-burned nor burned in a barrel. In both cases, the appropriate temperatures for a clean burn will not be achieved, and toxic contaminants, in particular dioxins and furans, will be released.

3.1.1 Conducting a Waste Audit or Estimating Waste Characteristics

A waste audit is the best way to define the waste stream at a given location. Ideally, an audit should account for seasonal variations in the waste generation rates, so it might have to be conducted in each season.

Performing a waste audit will provide an estimate of the total quantity of waste that could be generated, and allow the user to develop diversion activities that will reduce the amount of material requiring disposal. The residual waste remaining after diversion activities represents the waste requiring disposal. After other disposal options have been investigated, the characteristics of the remaining waste can be used to estimate the energy of the waste that will be charged to an incinerator. This information will be required to select an incinerator.

If the facility is only in the design stage a waste audit cannot be conducted. Even if a facility is operating, the cost of a waste audit could be seen as prohibitive. Where waste audits are not practical, it is still necessary to develop an estimate of the waste quantities and characteristics before a strategy for waste diversion and disposal can be finalized. Owners should investigate waste generation and diversion data from similar operations / facilities in order to develop an estimate of the waste types and quantities that will be generated at their facility. Sources of such information may include: industry associations; waste industry consultants; provincial / territorial authorities; and, other regulatory bodies.

3.1.2 Choosing Appropriate Waste Management Options

In all cases, reduction and diversion should be the primary waste management objectives, prior to considering any disposal option. Facilities should have a Waste Management Plan that outlines waste generation data and defines the acceptable recycling and disposal options. Hazardous waste and hazardous recyclable materials should be handled appropriately in accordance with local, provincial/territorial, and federal legislation.

3.2 Step 2: Select the Appropriate Incinerator (or Evaluate the Existing System)

The characteristics of the residual waste stream destined for incineration should be incorporated into a call for proposals from incinerator manufacturers. Specifying the quantity and composition of the waste stream will ensure that proposals include suitable incinerators. It should be noted that incinerators built for a specific waste stream, such as animal carcasses, liquid wastes and hazardous wastes, are available and should be used as required.

For facilities with existing incinerators, owners/operators should reassess the suitability of the existing system to manage the current waste stream.

For facilities incinerating **more than 26 tonnes of waste per year**, dual chamber controlled air incinerators are the recommended configuration. These systems are capable of incinerating a wide range of wastes and, when properly maintained and operated, will achieve emissions of PCDD/F and mercury below the level of the Canada-wide Standards. These systems should be equipped with a large secondary chamber sized to provide a residence time of at least one second at a temperature higher than 1000°C, to ensure complete combustion and minimize PCDD/F emissions.

For facilities incinerating **less than 26 tonnes of waste per year**, "determined efforts" as defined in the Canada-wide Standards for dioxins and furans[14] should be undertaken. Should circumstances restrict the ability to use a dual-chamber incinerator with a large secondary chamber, a single chamber incinerator with an afterburner should be used. It should be noted that such systems are less likely to be able to meet the emission standards than dual chamber incinerators.

The results of the waste audit conducted for the site should be provided to incinerator suppliers. Suppliers will be able to use these data to provide the appropriate type of incinerator. However, the owner should consider a number of issues when preparing the request for proposals. These include the type of incinerator that should be installed and the size of the incinerator. These issues are discussed in the following sections.

3.2.1 Classification of Batch Waste Incinerators

The emphasis in this report is on batch waste incinerators having a capacity of 50 to 3000 kg/batch. Even with this restriction there are various configurations of incinerators that could be used as noted in Table 3.2.

[14] Available on-line at: http://www.ccme.ca/ourwork/air.html?category_id=97

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Table 3.2 Batch Waste Incinerator Types and Features

FEATURE	TYPE
A. Number of chambers	1. Single-chamber (with afterburner)
	2. Dual-chamber
	a. Excess air in primary chamber
	b. Starved air in primary chamber, excess in secondary chamber
B. Waste feeding mode	1. Batch (one load per cycle)
	2. Intermittent (with ram feeder)
C. Ash removal mode	1. Batch
D. Air Pollution Control	1. No
	2. Yes (variety of technologies)
E. Use of blowers and fans	1. Forced air (blower(s) to supply air to combustion chamber(s))
	2. Combination (blower(s) AND an induced draft fan, necessary for APC systems)
F. Heat Recovery System	1. No
	2. Yes

3.2.2 Incinerator Selection Considerations

New Incinerators

For facilities incinerating **more than 26 tonnes of waste per year (tpy), the preferred incinerator for new installations is the dual chamber controlled air incinerator**. This type of incinerator has two chambers and each chamber is equipped with air ports that allow the quantity of air added in various parts of the incinerator to be controlled. These incinerators are capable of achieving the higher operating temperatures required to minimize the emissions of POPs, and in particular dioxins and furans.

As noted in Table 3.2 there are single chamber incinerators on the market. Suppliers may offer single chamber units equipped with afterburners, but they are not desirable. They are unlikely to provide the low emissions levels achievable by properly sized dual chamber incinerators. A properly sized secondary chamber is required to accommodate the volatile gases that are released from the primary chamber. Small secondary chambers are unlikely to provide sufficient time at elevated temperatures to ensure destruction of volatile compounds.

Another important factor to consider is the frequency of operation of the incinerator. While operating procedures should minimize the release of unwanted contaminants to the atmosphere, even during start-up and shut-down, there is a higher probability of emissions during these transition conditions than during the normal steady-state operation.

Incinerators sized in a way that allow them to operate only on alternate days, or even only 2 or 3 times per week, will generate lower annual emissions than those operated frequently each day. For this reason, a larger incinerator which can be operated less frequently is preferred.

The designer undertakes detailed calculations to size the incinerator and the control systems. Manufacturers recognize that wastes will not be consistent day after day and provide a margin of safety in their instructions. While the manufacturers would prefer tighter control on the feed rate, it is not unusual to see instructions state that the primary chamber should only be half filled. Based on the waste audit data, the manufacturer assumes a density and heat value for the waste and specifies a safe quantity of material that can be burned in a given cycle.

Existing Incinerators

If an existing incinerator is still being used as originally intended (i.e. the nature of the waste has not changed over the intervening years, and the unit has been properly maintained), consideration could be given to the unit's continued operation. Stack testing of the emissions can determine the incinerator's emission performance and allow the status of the emissions to be compared to the Dioxins and Furans Canada-wide Standards for incinerators.

Annual Throughput Considerations

The Canada-wide Standards for Dioxins and Furans[15] distinguishes incinerators by their capacity and use, setting an annual throughput threshold of 26 tonnes.

Any system capable of handling greater than 26 tonnes per year should have a primary chamber and a large secondary chamber sized to match the nature of the waste characteristics developed from the waste audit.

If the unit is unlikely to process 26 tonnes of waste per year, and a smaller secondary chamber is chosen to facilitate transport, additional care must be taken in ensuring the correct types of wastes and volume of material are charged to the primary chamber. This will reduce the possibility of high PCDD/F emissions.

Special Waste

Special wastes such as liquid waste (e.g. waste oil), wet waste (e.g. kitchen wastes, sludges), and animal carcasses require special consideration when selecting an incinerator. Liquid and wet waste in small quantities can usually be mixed with other wastes, but large quantities of either material will require special provisions.

For instance, waste oil can be used as an auxiliary fuel in an incinerator. Should its use be contemplated to offset virgin oils in the incinerator, this strategy should be made known to the manufacturer. They will recommend appropriate systems to separate sludge and moisture from the used oils, and the installation of two burners in each chamber (one for waste oil and one for virgin oil). These are necessary steps to ensure that temperatures in the chambers can be maintained should operating problems arise with the waste oil burner. In the context of the batch waste incinerators addressed in this report, liquid hazardous wastes, other than oil, should not be injected into the incinerator.

The incinerator hearth should be designed to contain any free liquid anticipated in the waste stream. Free liquids can drain into air ports if they are situated below the liquid level in the incinerator. Liquid may also leak through the doors of a standard flat hearth incinerator and damage their seals. Leaks in other areas can lead to poor combustion performance.

15 Available at: http://www.ccme.ca/assets/pdf/d_and_f_standard_e.pdf

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Wet waste is challenging to handle unless the incinerator is properly designed. For example, it is strongly recommended that batch incinerators not be used to treat sewage waste, unless they have been designed specifically for this type of waste. If it is anticipated that the waste to be incinerated on a routine basis will contain wet wastes, the auxiliary burner may need to be larger to dry the waste in a reasonable amount of time.

Unlike sludges and liquids, animal carcasses should not cause liquid leaks from the primary chamber even though they contain high levels of moisture. They must be handled in incinerators that can accept this type of waste. Animal wastes should only be charged to an incinerator that is capable of completely calcining the bones in order to ensure that all pathogens are destroyed in the incinerator. Those anticipating the need to destroy animal carcasses should discuss their needs with regulators and the manufacturers of waste incinerators.

3.3 Step 3: Properly Equip and Install the Incinerator

Building Considerations

- Incinerators should be installed inside a building to protect the equipment and the operators from weather conditions.
- In designing the installation site, care should be taken to maximize clearance between incinerator components, including the stack, and combustible construction materials.
- Insulation should be used to protect combustible building materials.
- The building should be equipped with sufficient fresh air inlet capacity for the incinerator. Both combustion air and dilution air for the barometric damper are required. Care should be taken to introduce air in a manner that does not lead to low-temperature operating problems.

Equipment Considerations

The incinerator system should come complete with the following equipment to monitor and record performance parameters:

- A scale to measure the weight of all materials charged to the incinerator; and
- A computerized process control and data acquisition system to store operating data from the incinerator.

Operational data should be collected and stored, at a minimum, every minute that the system is operating. The intent is to be able to summarize operating parameters during start-up, operation and cool-down for every cycle. If the required operating conditions are not achieved these data will allow the operators, the manufacturers and the regulator to identify the contributing factors for the failure. From this information, operating procedures can be adjusted to improve performance. Provisions should be made for the manufacturers to be able to remotely access and review the operating data for trouble shooting purposes.

It is highly recommended that batch incinerators not be equipped with heat recovery devices. The temperature of the stack gases in heat recovery systems will be lower than in systems without heat recovery, and may be in a temperature range that can lead to the formation of greater quantities of PCDD/F. Similarly, air pollution control systems are not recommended for batch waste incineration systems to control PCDD/F emissions. Stack gases should be released directly to the atmosphere at temperatures higher than $700^{O}C$ to reduce the chances of the inadvertent formation of PCDD/F through the *de novo* synthesis process.

If it is necessary to introduce additional waste to the incinerator during the burn cycle, the incinerator should be equipped with a ram charge system to limit the disruption of combustion in the primary chamber during the waste charging process.

3.3.1 Building Considerations

The recommendation from the previous section that incinerators be over-sized so they can be operated on a less frequent basis implies that the facility will need to store waste between incinerator operation periods. The incinerator should be installed in a building with sufficient space for waste storage. Operating the unit in a building will ensure that the operators are more comfortable and thus spend more time ensuring proper operation and conducting the necessary maintenance on the system. Furthermore, it will protect the unit from weather conditions, extend its life, and make operation more reliable.

Care must be taken to avoid the exposure of combustible building material to the high temperatures on the surfaces of the incinerator and the stack. Suitable fire proof insulation and air gaps must be provided to avoid igniting the building structure.

Since combustion reactions require air, provisions should be made to ensure that sufficient fresh air is available in the vicinity of the incinerator. The air flow should be unimpeded by louvers or doors in the building. At the very least, if louvers are required to isolate the incinerator room during power outages, their status should be interlocked to the incinerator controls so the incinerator does not operate when the dampers are closed. The manufacturer's advice should be sought on the fresh air supply requirements for the incinerator. It should be remembered that in extremely cold climates, fresh air impinging upon fuel lines or other parts of the operating system can created operating problems so the air should be properly tempered to minimize equipment freezing and/or staff discomfort.

3.3.2 Equipment Considerations

The operation of the incinerator should be monitored at all times and this data should be recorded to provide a record of such operation. A list of monitoring equipment recommended for all installations follows:

- **Weigh Scale:** Every incinerator operation should have a weigh scale so that every load can be weighed and the results recorded.
- **Continuous Monitoring:** In order to confirm the status of the incinerator at all times, it is recommended that measurements of the parameters described below be continuous regardless of the operational status of the incinerator. Gaps in the readings could be interpreted as periods where the incinerator was not operating in an appropriate manner. Thus, continuous readings, once per minute, are the best way of proving that the system is operating in compliance with the various approvals and guidelines. The measurements should be captured in a computerized data acquisition system that logs the date and time of the readings as well as the readings themselves.
    - **Temperature:** The most basic of all measurements associated with incinerator operation is temperature. Temperature should be monitored in both the primary and secondary chamber and the stack at all times. The sampling location for the stack measurement should be above the barometric damper if one is installed. Such measurements will ensure that the system has achieved the desired temperature levels. Temperatures outside the normal range can serve to warn the operator that the system is not working as intended.
    - **Differential Pressure in the Primary Chamber:** A second operating parameter that is important is the differential pressures in the primary chamber. The

primary chamber should operate at negative pressure. Should the differential pressure track towards the positive, it is an indication that insufficient draft is present in the system and combustion fumes could be building in the system. The operator should be able to adjust this parameter either by changing the inlet flows or adjusting the barometric damper. If the pressure goes too negative, the combustion air fans may have failed, or the damper needs adjustment. The data acquisition system can be programmed to warn the operator of potential draft limitations in the system.

- **Auxiliary burner operation:** The auxiliary fuel burners in some incinerators are not reliable. This type of failure will likely be reflected in lower than desired temperatures in the incinerator. A combination of no fuel flow in the auxiliary burners and low temperatures in either chamber could indicate an auxiliary burner failure. The operator should be able to monitor the auxiliary burner operation.
- **Fan Amperage:** Failure of the combustion air fans will lead to inappropriate operating conditions. Recording the fan amperage will provide some indication that the fans are operating at their design loads.
- **Interlocks:** The data acquisition system should monitor the state of all interlocks on the system. Loading doors and other components of the system are frequently connected to the incinerator control system. Recording the status of sensors on various doors or dampers will assist in confirming the system is operating in the desired manner.

The type of data acquisition system described above can store data and can also be used as a means of allowing the manufacturer to look at operational data remotely to assist with trouble shooting the operation. In this manner, the operator can quickly obtain the assistance of the manufacturer. Owners should request that the manufacturer provide recommendations for the data acquisition system. This will likely open up a line of communication concerning what they can do to help operational staff adjust the incinerator if it is not operating correctly.

Other Considerations

Most batch incinerator systems are factory fabricated and shipped to the site where they are to be used. Larger systems may be shipped in sections to be assembled on the site. Typically the stack will be installed on the incinerator as one of the final steps. Stacks should be properly designed to ensure that emissions can freely disperse in the atmosphere and not be re-entrained into fresh air intakes on nearby buildings.

3.4 Step 4: Operate the Incinerator for Optimum Combustion

Operational Considerations

Wastes received at the incinerator building should be separated according to their heating value characteristics: wet or low-energy wastes (e.g. food waste); mixed wastes with average energy values; and other materials with high energy values, such as oily waste materials. To facilitate this separation, all waste should be collected in transparent bags. To further assist with separation, wastes could be collected in coloured-coded bags.

Batch incinerators are designed to accept wastes within a specified range of energy (i.e. calorific) values. The operator should select waste from each category and mix it to achieve the manufacturer's specified input calorific value. Each bag should be weighed, its source should be noted, and the total weight of each category should be tallied before completing the loading. This information should be recorded by the computerized data acquisition equipment installed with the incinerator. (Refer to step 6 for further record keeping requirements).

Batch incinerator systems have limited charging capacity (both in terms of waste quantity and the calorific value of the waste charge). To assist the operator with the charging task, particularly for smaller incinerators, several batches could be weighed and placed in their own containers prior to loading the incinerator. The same weighing and logging procedures should be used for each batch and, once recorded, the batch can be charged when appropriate.

When the incinerator is charged with the appropriate mix and quantity of waste, the operator should close the door, ensure all interlocks are engaged, and start the burn cycle. The operator should observe the burn for at least 15 minutes after ignition of the primary chamber burner to ensure the volatility of the waste charged is not creating too much gas for the secondary chamber to handle. The rate of combustion can be slowed by reducing the quantity of under-fired air. The primary chamber should be operated in the temperature range specified by the manufacturer (typically 500^{O}C to 800^{O}C).

When satisfied that the burn is proceeding in a controlled manner, the operator may leave the incinerator area while the equipment completes the burn cycle.

The burn cycle should not be interrupted by opening the charging door until after the burn is complete and the unit has cooled down. No additional waste should be added to the primary chamber unless the incinerator is equipped with an appropriate ram feed device.

When the burn is complete and the unit has cooled, the operator should open the door only when wearing protective equipment such as gloves, dust mask, face shield and goggles.

The operator should remove the ash from the previous burn cycle before reloading the incinerator. Any unburned materials found in the ash should be recharged to the primary chamber after the operator has cleaned the air ports, and before putting a fresh charge into the incinerator.

Training Considerations

Operators should be properly trained by the incinerator manufacturer. The training course should include, as a minimum, the following elements:

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- System safety including identification of hazards that the operator should recognize;
- Waste characterisation and how waste composition can affect operation;
- Loading limitations, including materials that should NOT be charged to the incinerator, and the allowable quantities of different types of wastes that can be charged;
- Start-up procedures for the incinerator and the normal operation cycle;
- Operation and adjustment of the incinerator to maximise performance;
- Clean out procedures at the end of the cycle;
- Troubleshooting procedures;
- Maintenance schedule; and
- Record keeping and reporting.

Managers should be involved in the training session so that continuity can be maintained with different operators.

3.4.1 Operation

3.4.1.1 General Batch Waste Incinerator Operation Considerations

<u>Effect of Waste Characteristics</u>

The characteristics of the waste loaded to the incinerator will affect the temperature profile in the various sections of the incinerator during the burn cycle. These variations will also influence the duration of auxiliary burner operation.

Wastes with a high percentage of volatile matter (e.g. paper >75%, plastics >85%) will release more volatile gases from the primary chamber than wastes with low percentage of volatile matter (e.g. vegetable wastes <20%). When mixed with additional air in the secondary chamber, the combustion of the volatile gases maintains the secondary chamber operating temperatures and limits the need for auxiliary fuel. At this point in the burn cycle, the temperature in the secondary chamber will be higher than that in the primary chamber. However, as the release of volatile gases from the primary chamber decreases, combustion in the primary shifts and begins to consume the fixed carbon. This results in a drop in temperature in the secondary chamber and an increase in temperature in the primary chamber. The secondary temperature can drop to the point where the secondary chamber auxiliary burner must come on to maintain the temperature at or above the required setpoint, typically 1000°C.

Higher moisture levels in the waste require more auxiliary fuel to evaporate the moisture and allow the waste to burn. The moisture released in this way passes through the secondary chamber taking heat from that chamber as well. This could mean that the secondary burner must operate for longer periods during the early phases of the cycle.

The ash percentage in the waste can also influence auxiliary fuel consumption and overall cycle time. The ash must be heated to sufficient temperatures to drive off volatile gases and the fixed carbon. The ash remaining in the primary chamber retains heat and lengthens the time required for the incinerator to cool so it can be handled safely.

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Incinerator Loading

To properly load the incinerator, the following steps need to be followed:

- Determine the source of the waste – kitchen, vehicle shop, bunkhouse area, etc.;
- Weigh the waste to determine how much must be disposed; and,
- Proportion the waste fed to the incinerator on the basis of the anticipated heating value.

The wastes from different operations in the facility would need to be designated, either by colour codes or in different waste containers. Each source would be assumed to produce waste that was similar in composition on a daily basis.

For batch waste incinerators with charge sizes between 50 kg and 200 kg, individual bags of waste can be weighed before they are put into the incinerator.

For larger batch incinerators it would likely be onerous to have to weigh each bag in a 1,000 kg charge and alternative approaches could be adopted. The incinerator building should have a tipping floor sized to allow segregation of the various types of waste streams. All waste arriving at the facility should be weighed before being placed in the appropriate area. Knowing the mass of waste in each pile, the incinerator could be loaded with the appropriate volume of a specific type of waste to create a mixed load that has an appropriate calorific input for the incinerator. Possible mixes could be developed from the waste characteristics so the operator has clear guidance on loading the incinerator. For instance adding some higher calorific value plastic waste to the kitchen waste could reduce the amount of auxiliary fuel needed to evaporate the moisture. It is important to segregate known high calorific value materials so that the quantity of these materials in a batch can be limited.

Controlling Air

Ideal combustion is achieved when the exact amount of air needed to oxidize the carbon and hydrogen in the waste is supplied to the incinerator. This stoichiometric air addition rate will result in the highest temperatures from burning a given batch of waste. If too little or too much air is supplied, the temperatures in the primary chamber will change. Indeed, controlling air is the basis of many batch waste incinerators.

The typical starved air incinerator operates by controlling the primary chamber air injection so that the primary chamber operates under sub-stoichiometric or pyrolytic conditions. The air added to the system is only sufficient for the primary chamber to reach pyrolysis temperatures. This is typically between 70% and 80% of the ideal amount of air needed to burn the waste.

The volatile gases from the primary chamber can be burned in the secondary chamber after being mixed with extra air. The amount of air in the secondary chamber is typically 140% to 200% of the amount required to complete the reaction in the secondary chamber. Part of this excess air is added to control temperatures in the secondary chamber as explained below.

If too little air is supplied to the primary chamber the temperature will drop because the waste cannot burn sufficiently to increase the temperature. The operating ideal is to allow the waste to burn at a rate that generates sufficient volatile gases to maintain the desired temperature in the secondary chamber. If too much air is added in the primary chamber the combustion rate is accelerated and much of the volatile gases will consumed before they get to the secondary chamber. This will lead to higher temperatures in the primary chamber, premature failure of refractory and potentially other damage to the incinerator. In turn, because insufficient volatile gases will pass to the secondary chamber, the temperature in the secondary chamber will be lower and the auxiliary burner will need to operate to maintain temperature. Adding additional air to the secondary chamber will decrease the temperature in the secondary chamber, while limiting air addition will raise the temperature. This is opposite to the temperature response to additional air in the primary.

Controlling the amount of air added to the incinerator can be done in a number of ways:

- Manually by the operator;
- Automatically based upon the temperatures in the primary and secondary chambers; and,
- Automatically based upon changes in the oxygen level in the gas stream.

The control methods represent an increasing level of complexity so oxygen sensors are usually found only on larger systems. The operator must understand the cause and effect when making changes to the system and should be present for the duration of the cycle if manually controlling the operation. For this reason, automatic temperature sensing controls are preferred for batch incinerators.

Controlling Temperature

The primary chamber should be operated in the appropriate temperature range (typically 500^{O}C to 800^{O}C) specified by the manufacturer.

During operation, the secondary chamber temperature is controlled by varying the amount of air introduced to the secondary chamber and by operating the secondary chamber burner. As discussed earlier, regulators usually specify the secondary chamber temperature set point in the range of 850 ^{O}C – 1000 ^{O}C. The secondary chamber temperature set point may vary by jurisdiction and according to the residence time in the secondary chamber. As noted above, adding air to the secondary chamber decreases its temperature, while decreasing the amount of air raises its temperature. A secondary chamber temperature sensor controls the operation of the secondary burner. This sensor has low and high temperature set points that govern burner operation on pre-heating of the secondary. If the temperature drops below the selected set point the burner comes back on to increase the temperature. To avoid having the air and burner control compete with each other, the set point for the air control system is usually set at least 40^{O}C above the burner's high temperature set point.

Typical Problems

Temperatures indicate how the combustion system is performing. Another way to judge the operation of the incinerator is to observe the colour of the flame in the two chambers. Hotter temperatures will drive the flame colour from dull red, through orange to yellow. In the primary chamber any colour brighter than dull red would suggest that too much air is being introduced into the system. In the secondary chamber, red flames indicate a temperature around 760^{O}C, which is generally considered to be too low. An orange flame will be seen in the 1,100^{O}C temperature range whereas at 1,200^{O}C yellow flames are an indication that the temperature is too high for normal waste destruction.

Typical operating problems with batch waste incinerators are:

- **High fuel consumption**

  High fuel consumption occurs when the operator is trying to burn extremely moist waste, or when too much air is added to the system.

  As noted earlier, water must be evaporated from the wet waste before volatilization can occur. Since heat is not released from the waste until it starts to volatilize, the auxiliary burner must supply the extra energy needed. To reduce energy consumption, one must limit high moisture waste in any particular load.

  If the combustion chambers have leaks, excess air will be introduced to the incinerator. Air could enter the incinerator through doors that have become warped due to over heating, or through deformed seals or holes in the incinerator due to corrosion. If excess air is introduced in the primary chamber, the volatile gases will be partially burned in the primary chamber and will not be available to heat the secondary chamber. If excess air enters the secondary chamber, temperatures will drop and the burner will operate for longer periods.

- **The formation of fused ash, or clinker, in the primary chamber**

  Clinkers form when localized temperatures of the ash bed lead to melting of the ash and fusing of the melted material. With municipal solid waste, this occurs at temperatures above 1,200^{O}C. While this should be far above the operating gas temperature of the primary chamber (typically 500^{O}C to 800^{O}C), localized bed temperatures can be higher than the gas temperature. Wherever air is introduced into the primary chamber, there will be zones where the stoichiometric amount of air is present for complete combustion. This air addition rate will result in the highest combustion temperatures possible (in excess of 1,500^{O}C). This condition is more likely to occur if a harsh jet of air is introduced into the primary chamber due to blocked air ports. If this occurs, the flames near the bed would be bright yellow. The operator needs to check the air ports and ensure that the air is evenly distributed throughout the primary chamber each time he removes ash from the incinerator. Cleaning the air injection ports will limit clinker formation.

- **Visible stack emissions**

  The appearance of the stack plume can also provide some indication of the adequacy of the combustion process. Typically stack emissions increase when there is one or a combination of the following situations occurring:

  - The high set point temperature in the secondary chamber is too low;
  - Excessive air infiltration;
  - Excessive negative draft;
  - Excessive primary air addition;
  - Excessive secondary air addition; or,
  - Waste characteristics that prevent the unit achieving design settings.

Plume Characteristics

Figure 3.2 shows different conditions that may be observed with malfunctioning dual chamber controlled air incinerators.

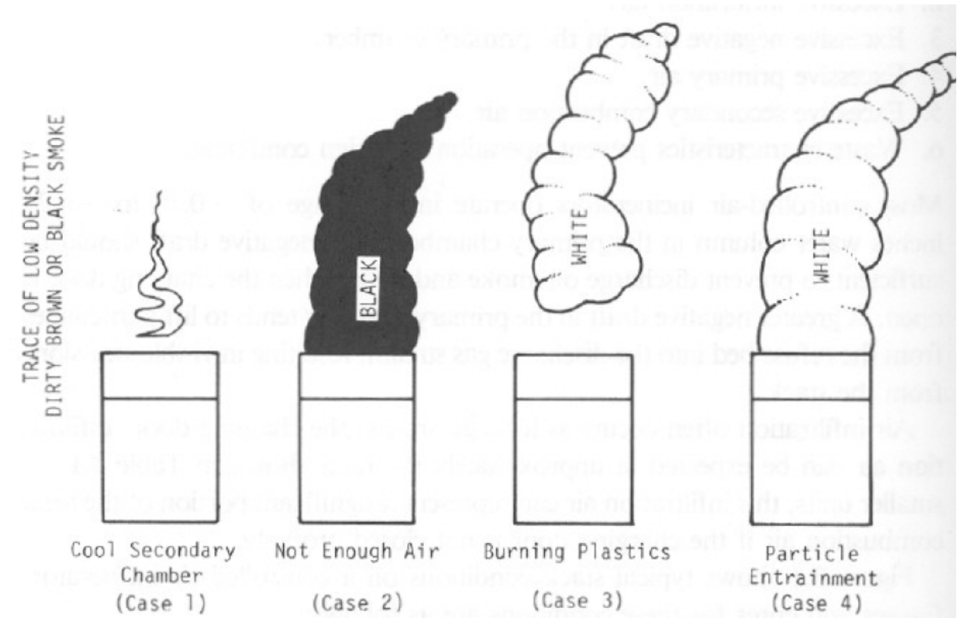

Figure 3.2 Plume Characteristics related to Operating Conditions [16]

Case 1, with traces of dirty brown or black smoke in a wispy plume, generally occurs when the secondary chamber set point temperature is too low. Raising the temperature in the secondary chamber should improve the situation. Secondary chamber temperatures could also be low due to burner failure. Incinerators should not be operated without functioning secondary chamber burners.

Case 2 is the classic "not enough air for the waste being burned" situation as black smoke indicates incomplete combustion. There are a series of steps that the operator should go through to rectify this situation:

- increase the air flow to the secondary chamber to the maximum;
- reduce the air flow to the primary chamber to reduce the rate of volatilisation; and/or
- temporarily increase the set point of the auxiliary burner to 1,200^{O}C to overcome the burning of a very high calorific waste charge.

If the situation persists after these steps have been taken, check the charging capacity for the

[16] Cross, F.R, and H.E. Hesketh, 1985. Controlled Air Incineration. Publishing by Technomic Publishing Company Inc. ISBN No. 87762-396-1

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incinerator and the characteristics of the wastes being burned. If the energy content of the waste is very high, the amount of that waste charged to the incinerator will need to be reduced in the future.

Case 3 is a detached white plume that could be the result of burning chlorinated wastes. Hydrogen chloride can cause this type of plume in high concentrations. To rectify this situation, ensure that chlorinated plastics are segregated from the waste stream.

Case 4 is a white plume that persists for long distances downwind. It is indicative of high quantities of fine particulate matter in the stack gases. This can be caused by high rates of air addition to the primary chamber, or by the particular components in the waste stream. If reducing the primary air flow does not rectify this situation, the operator needs to determine the types of materials being burned and take steps to reduce or eliminate their introduction to the system.

High moisture levels in a plume, particularly when exhausting into cold air, will also appear to be white. Water vapour forms a mist as it comes out of the stack and takes on the appearance of a white plume. This plume dissipates rapidly as the plume travel downwind and as the saturated air mixes in the atmosphere reducing moisture levels. The difference between Case 3, Case 4 and a high moisture plume is that typically the moisture plume will only exist for a short distance downstream of the stack. Moreover, the high moisture plume will typically not be visible as the plume exits the stack, but rather appears to form some distance above the stack tip as the vapour condenses in the cold atmosphere.

3.4.1.2 DOs and DON'Ts of Incinerator Operation

It is important to ensure that the incinerator is operating properly according to its design purpose. The following figure provides some significant DOs and DON'Ts to consider when operating a batch waste incinerator.

Some Significant DOs and DON'Ts of Batch Waste Incineration

DO:

- Use specially designed incinerators to dispose of animal carcasses, sewage, liquid wastes, or hazardous waste materials.
- Develop a waste collection and handling program that will allow the operators to mix the waste to provide a uniform heat input to the incinerator;
- Use waste oil and waste fuel for other heating purposes where practical, rather than disposal through incineration;
- Limit the quantity of waste oil or waste fuel in any specific charge to the incinerator to ensure the energy contained in the waste charge is within the limits specified by the manufacturer;

DO NOT:

- Overload the incinerator.
- Put mercury containing waste (e.g. fluorescent lamps, thermometers, thermostats, dental amalgam, batteries) into the incinerator. Limiting the quantity of mercury placed in the incinerator is the most effective way to limit mercury emissions.
- Introduce metal and glass into the incinerator when alternative options exist (e.g. recycling, landfilling). These materials absorb energy from the furnace and increase the wear and tear on various incinerator components.
- Incinerate wastes containing heavy metals (e.g. mercury-containing wastes, wood treated with Chromated Copper Arsenate (CCA), lead paint).
- Incinerate asbestos waste.
- Introduce large quantities of plastics or high calorific wastes into incinerators designed for low calorific value wastes such as animal carcasses and food waste. Incinerators capable of disposing of low calorific value waste are not suited to burning large quantities of high calorific wastes.

3.4.1.3 Standard Operating Procedures

To ensure good operation of the incinerator, there are certain standard operating procedures that should be followed. The list below should serve as a starting point for building the site specific procedures. These procedures must be tailored to the individual facility, and all operators should be trained to follow the site specific version of these procedures.

Cleaning and Loading

- The primary chamber should be cleaned of all ash before any new charge is introduced. Operators should check to ensure that the previous cycle is complete and that the primary chamber has cooled to room temperature before commencing clean out.
- Turn OFF all power to the incinerator before opening the primary chamber door.
- Wear personal protective equipment (gloves, face shield, dust mask) and use appropriate equipment to remove the ash. Rake and shovel the ash from the hearth and place it in a metal container for transport to an approved disposal site.
- Material that was not completely reduced to ash should be placed into the primary chamber for the next burn cycle. If it is necessary to remove this material for inspection and maintenance of the chamber it should be placed in a metal container until it can be reloaded to the incinerator. If this material is still smouldering, it should be sprayed with water when in the metal container.
- Inspect the interior of the primary chamber for wear, or damage to refractory. Refractory that has failed should be replaced before using the incinerator for the next cycle.
- Clean all the air pipes into the primary chamber. Vacuum the pipes to remove fine materials and carefully chip away any slag around the tip of the air pipes, so as not to damage the air pipes.
- Inspect all the door seals to ensure that the door will maintain a tight seal upon closure. Clean any deposits from the seals. Replace seals that are damaged, worn or crushed.
- Clean the inspection view ports.
- Measure and record the weight of the materials to be combusted on the next burn cycle. Fill the primary chamber with the material to be combusted on the next burn cycle. Ensure waste loaded to the primary chamber does not block the burner. Follow the manufacturer's instructions concerning the mass or volume of waste that can be loaded.

Pre-Start Check

- Close and lock the primary chamber door. Ensure that all the latches are properly engaged and that the PRIMARY DOOR CLOSED safety switch is energized.
- Check that no alarms are displayed on the operating panel.
- Ensure that all the temperature set points are at the correct settings.
- Ensure that the cycle times are appropriate for the nature of the waste (volume, energy content, moisture, density, etc.). Typically the burn cycle will be 2 to 6 hours in duration with the cool down cycle being approximately 2 to 3 hours.
- If the incinerator is equipped with an EMERGENCY STOP BUTTON ensure that it is properly armed and that it is unlocked and pulled out.

- Ensure that primary and secondary manual air dampers are 100% open. Set all fuel valves to the open position.

Starting the Burn

Typically the operator will push the start button for the burn cycle and the control system will take over the operation of the incinerator. The operator should observe the operation during start-up to ensure that the following steps are completed.

- Starting the cycle will initiate an air purge of the chambers. This is followed by a purging of the secondary chamber burner prior to igniting. As the secondary burner operates, the temperature in that chamber will rise. When the temperature reaches the appropriate set point, the primary chamber burner will purge and ignite.
- If the secondary burner does not raise the temperature to the manufacturer's recommended set point, the operator should not override the controls and continue the burn. Any failures during the start-up should result in the incinerator shutting down. At this time the operator will need to commence fault identification procedures to overcome the deficiencies.
- The incinerator control system should maintain proper operating conditions throughout the timed burn cycle. Following the burn cycle, the system will go into a cool down mode. During this period air is introduced into the primary chamber to speed the cool down.
- Under no circumstances should the operator attempt to open the primary chamber doors when the system is operating. This practice can cause flashbacks that can injure personnel. The extra air entering the primary chamber will disrupt the combustion process, possibly leading to increased emissions.

3.4.1.4 Preventative Maintenance

All mechanical equipment requires routine preventative maintenance to operate efficiently. The operating conditions for the equipment dictate how frequently maintenance should be carried out. Incinerators have a service cycle that involves repeated heating to high temperatures followed by cooling. This can lead to refractory failures. Furthermore, moving waste and ash into and out of the incinerator creates wear on surfaces. Surfaces need to be refurbished on a routine basis and the seals around the openings require regular inspection and replacement as necessary.

Incinerators are waste disposal devices and should be managed in a manner similar to other disposal options. Incinerator owners need to recognize that money will be required to maintain the facility and to mitigate any unexpected events.

In addition, money should be set aside for routine maintenance. The cost of maintenance will be proportioned between labour, maintenance supplies, and equipment replacement. At least 3-5% of the capital cost of the unit should be set aside for annual maintenance and capital equipment replacement.

The maintenance budget should also include a capital reserve fund to cover repair and upgrades necessitated by unbudgeted circumstances. A suggested allowance for this would be 20% of the annual maintenance costs, labour and supplies, or about 1% of the capital cost.

The owner should consider establishing a service contract with the manufacturer (or a manufacturer-trained/ qualified local technician). These people should visit the site annually, and preferably quarterly if the incinerator is used daily. The owner should discuss the costs of such a program with the manufacturer and inquire about assistance the manufacturer can provide if the incinerator control and operating system can be accessed remotely.

Thus annual maintenance and capital reserve fund costs should be on the order of 4 - 6% of the original cost of the incinerator system.

3.4.2 Training

The cornerstone of ensuring good operation of any incinerator is that the staff understands how the system operates and takes appropriate steps to ensure the continued good operation of the equipment[17].

Every incinerator manufacturer has its own unique approach to designing incinerators. The control systems, while following the general logic of the previous section, are likely to differ as well. Any person who will be operating an incinerator should be trained by the manufacturer before being asked to operate it. It is not good practice to have operators train operators. The manufacturer and its agents are the people most familiar with good operating procedures that will ensure minimal emissions.

Management staff should be involved in the training sessions wherever possible. Management are likely to provide long-term continuity at most sites. They can assist operators with their tasks, and ensure that substitutes or replacements are suitably trained.

Chandler, A.J., 2007. Review of Dioxins and Furans from Incineration In Support of a Canada-wide Standard Review. A Report Prepared for The Dioxins and Furans Incineration Review Group through a contract associated with CCME Project #390-2007. Available at: http://www.ccme.ca/assets/pdf/1395_d_f_review_chandler_e.pdf August 18, 2008.

3.5 Step 5: Safely Handle and Dispose of Incinerator Residues

Ash from the primary chamber of the incinerator can contain materials deleterious to the operator's health and the environment. Operators should use personal protective equipment when handling this material. The material should be carefully removed from the hearth and placed in covered metal containers suitable for transporting the ash to an approved disposal site. The operator should weigh, and maintain records of, the quantity of ash produced.

3.5.1 Residue Handling Practices

The quantity of ash (residues) generated by the facility should be documented, and the facility's weigh scale should be used to determine the mass of ash that is shipped from the facility to the disposal site.

For every 1000 kg of waste burned, approximately 300 kg of bottom ash is generated[18]. If the quantity of ash exceeds this amount, the material should be examined to determine whether the increased mass is due to the presence of non-combustible materials, or because there is a high quantity of unburnt carbon in the ash. If the latter situation is the case, operation of the incinerator should be adjusted to enhance the oxidation of carbon.

Representative samples of the bottom ash should be collected and forwarded to a laboratory for leachate toxicity testing. The International Ash Working Group provides guidance on sampling and analysis of ash[19]. At least 10 samples of ash are required to adequately characterise the material, and as a precaution it is recommended that testing on each sample be completed in triplicate. The results of the tests should be forwarded to the appropriate regulatory agency.

[18] International Ash Working Group, 1997. Municipal Solid Waste Incinerator Residues. Published by Elsevier, ISBN 0-444-82563-0.
[19] Ibid

3.6 Step 6: Maintain Records and Report

To demonstrate appropriate operation and maintenance of the incinerator, the facility should maintain records and prepare an annual report containing at least the following information:

- A list of all staff who have been trained to operate the incinerator; type of training conducted and by whom; dates of the training; dates of any refresher courses;
- All preventative maintenance activities undertaken on the equipment;
- Records of operation of the incinerator - in electronic format with full data backup;
- Summarized annual auxiliary fuel usage;
- A list of all shipments of incinerator residues, including the weight transported and disposed of by type if necessary, and the location of the disposal site;
- Results of any emissions measurements or any ash sampling data collected during the period.

All raw data records from the operation of the incinerator should be retained for inspection by the appropriate authorities for the period designated by those authorities, or for at least 2 years. The owner should work with the incinerator manufacturer or supplier and the regulators to determine the appropriate level of summary data that should be sent to the regulatory body (e.g. federal, provincial/territorial). The reports should be approved by the facility's senior management before submission.

Recording:

One of the most important records that should be available for review by the regulators is the maintenance log. This should record routine maintenance activities, date completed, by whom, and any problems encountered. This routine maintenance should correspond to the preventative maintenance recommendations provided by the manufacturer. A record should be kept of any upsets or equipment failures that necessitated special maintenance activities. The data for special maintenance activities should include the description of the issue being addressed, the date the work was completed, and who was responsible for that work. Most importantly, the operators/maintenance personnel should analyse the cause of the failure and ascertain if there are operating procedures that can avoid a repeat of the failure.

Continuous monitoring (once per minute) of incinerator operation should be recorded regardless of whether or not the incinerator is in use. To prevent any uncertainty about the waste disposal data, the information on the quantity of waste incinerated should be cross referenced by date and start time to the incinerator operating data. While some might question the usefulness of collecting operating data when the incinerator is not operating, a complete record for all 8760 hours of the year will validate the production data.

Reporting:

Licenses issued to waste disposal operators in all parts of Canada require some degree of reporting on operations to the appropriate authorities. There is some basic information that should be included in any report:

- **Quantity of Waste Incinerated:** Since the CWS for PCDD/F and Mercury both set limits on the amount of waste that can be burned before different levels of proof of compliance are required, the basic measurement for every incinerator site must be the quantity of waste charged to the incinerator during the year. Because the incinerator is limited to a fixed quantity of waste on every charge, each load should be recorded separately, and the quantities totaled for the year, and preferably weekly and monthly. Such data will also assist the owner in determining waste generation rates at the facility, and in turn, provide data on the effectiveness of diversion and reduction programs.

- **Operating Data:** Operating data that is important are temperatures, carbon monoxyde, and oxygen levels, along with other data such as differential pressures and auxiliary burner operating times. If the auxiliary burners are of fixed output, it would be satisfactory to record the signal controlling its operation. If the input is variable, motor amperage from the pump would provide some indication of the rate of fuel use. Raw one minute monitoring data should be preserved in electronic format for analysis.
- **Ash shipment weights:** The report should include ash shipment weights and the name of the operator for any particular load along with notes on observations or problems experienced with the load.
- **Auxiliary fuel receipt data:** Auxiliary oil receipt data should be recorded in the log book and receipts for the shipments should be kept for verification by regulators.
- **Training:** The report should contain records of the training received by the staff, who conducted the training and when.
- **Changes in Operation:** Any major changes to the operation should be noted in the annual report, as should the results of any testing undertaken on the stack emissions or ash.

It is important to note that waste any incinerators incinerating: ≥ 26 tonnes of non-hazardous solid waste per year, ≥ 26 tonnes of biomedical or hospital waste per year, hazardous waste, or sewage sludge must report emissions of PCDDF, hexachlorobenzene, and mercury under the National Pollution Release Inventory (NPRI). For more information, please see www.ec.gc.ca/inrp-npri/.

Appendix F: Environmental Guideline for the Burning and Incineration of Solid Waste

Environmental Guideline for the

Burning and Incineration of Solid Waste

Department of Environment
Government of Nunavut

GUIDELINE: BURNING AND INCINERATION OF SOLID WASTE

Original: October 2010
Revised: January 2012

This Guideline has been prepared by the Department of Environment's Environmental Protection Division and approved by the Minister of Environment under the authority of Section 2.2 of the *Environmental Protection Act*.

This Guideline is not an official statement of the law and is provided for guidance only. Its intent is to increase the awareness and understanding of the risks, hazards and best management practices associated with the burning and incineration of solid waste. This Guideline does not replace the need for the owner or person in charge, management or control of a solid waste to comply with all applicable legislation and to consult with Nunavut's Department of Environment, other regulatory authorities and qualified persons with expertise in the management of solid waste.

Copies of this Guideline are available upon request from:

Department of Environment
Government of Nunavut
P.O. Box 1000, Station 1360, Iqaluit, NU, X0A 0H0
Electronic version of the Guideline is available at http://env.gov.nu.ca/programareas/environmentprotection

Cover Photos: Nunavut Department of Environment (left and bottom right), Aboriginal Affairs and Northern Development Canada (top right)

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APEX Geoscience Ltd.

Introduction

People living and working in Nunavut often have limited options available for cost effective and environmentally sound management of household and other solid waste. The widespread presence of permafrost, lack of adequate cover material and remote locations make open burning and incineration a common and widespread practice to reduce the volume of solid waste and make it less of an attractant to wildlife. A wide variety of combustion methods are used ranging from open burning on the ground to high temperature dual-chamber commercial incinerators. Generally, high temperature incinerators are more expensive to purchase and operate and cause less pollution than do the less expensive and lower temperature methods. However, high temperature incinerators can safely dispose of a wider variety of waste than can the lower temperature open burning methods.

The Guideline for the Burning and Incineration of Solid Waste (the Guideline) is not intended to promote or endorse the burning and incineration of solid waste. It is intended to be a resource for traditional, field and commercial camp operators, communities and others considering burning and incineration as an element of their solid waste management program. It examines waste burning and incineration methods that are used in Nunavut, their hazards and risks and outlines best management practices that can reduce impacts on the environment, reduce human-wildlife interactions and ensure worker and public health and safety. This Guideline does not address incineration of biomedical waste, hazardous waste and sewage sludge. The management of these wastes requires specific equipment, operational controls and training that are beyond the scope of the current document.

The *Environmental Protection Act* enables the Government of Nunavut to implement measures to preserve, protect and enhance the quality of the environment. Section 2.2 of the *Act* provides the Minister with authority to develop, coordinate, and administer the Guideline.

The Guideline is not an official statement of the law. For further information and guidance, the owner or person in charge, management or control of a solid waste is encouraged to review all applicable legislation and consult the Department of Environment, other regulatory agencies or qualified persons with expertise in the management of solid waste.

1.1 Definitions

Biomedical Waste	Any solid or liquid waste which may present a threat of infection to humans including non-liquid tissue, body parts, blood or blood products and body fluids, laboratory and veterinary waste which contains human disease-causing agents, and discarded sharps (i.e. syringes, needles, scalpel blades).
Bottom Ash	The course non-combustible and unburned material which remains at the burn site after burning is complete. This includes materials remaining in the burn chamber, exhaust piping and pollution control devices where such devices are used.
Burn Box	A large metal box used to burn solid waste. Combustion air is usually supplied passively through vents or holes cut above the bottom of the box. An exhaust pipe or stack may or may not be attached.

Commercial Camp	A temporary, seasonal or multi-year facility with a capacity greater than 15 people and which has been established for research, commercial or industrial purposes. A commercial camp does not include a traditional camp or field camp.
Commissioner's Land	Lands that have been transferred by Order-in-Council to the Government of Nunavut. This includes roadways and land subject to block land transfers. Most Commissioner's Land is located within municipalities.
Contaminant	Any noise, heat, vibration or substance and includes such other substance as the Minister may prescribe that, where discharged into the environment, (a) endangers the health, safety or welfare of persons, (b) interferes or is likely to interfere with the normal enjoyment of life or property, (c) endangers the health of animal life, or (d) causes or is likely to cause damage to plant life or to property.
Determined Effort	The ongoing review of opportunities for reductions and the implementation of changes or emission control upgrades that are technically and economically feasible and which result in on-going reductions in emissions. Determined efforts include the development and implementation of waste management planning which is focussed on pollution prevention.
De Novo Synthesis	The creation of complex molecules from simple molecules.
Environment	The components of the Earth and includes (a) air, land and water, (b) all layers of the atmosphere, (c) all organic and inorganic matter and living organisms, and (d) the interacting natural systems that include components referred to in paragraphs (a) to (c) above.
Field Camp	A temporary, seasonal or multi-year facility consisting of tents or other similar temporary structures with a capacity of 15 people or less and which has been established for research, commercial or industrial purposes. A field camp does not include a traditional camp or commercial camp.
Fly Ash	Unburned material that is emitted into the air in the form of smoke or fine particulate matter during the burning process.
Hazardous Waste	A contaminant that is a dangerous good and is no longer wanted or is unusable for its original intended purpose and is intended for storage, recycling, treatment or disposal.
Incineration	A treatment technology involving the destruction of waste by controlled burning at high temperatures.