

Bennett Environmental Inc
Proposed Kirkland Lake Thermal
Oxidizer Facility

Proposed Terms of Reference

Pursuant to the Environmental Assessment Act

Background Document 4
Rationale for Incinerator Design

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1 Incineration Technology for the Proposed Facility

This document addresses Bennett Environmental Inc.'s (BEI) incinerator design for the proposed thermal treatment facility in Kirkland Lake, Ontario. It contains the rationale for the selection of systems to be incorporated into BEI's primary and secondary combustion chambers as well as an evaluation of air pollution control technologies for acid gases, metals, organics and particulate. This document also examines which combination of air pollution abatement options are the most suitable, considering stack emissions, quantity and quality of residues, stability of contaminants in these residues, residue disposal, and operational factors.

The first five sections of the document reviews literature supporting the emission standards selected for parameters of concern. Design philosophy and equipment selection criteria are based solely to meet the waste destruction and emission abatement efficiencies targeted.

2 Emission Standards for Proposed BEI Thermal Destruction Unit

BEI proposes to design the treatment facility to meet Ontario A-7 Guidelines and Canadian Council of Ministers of the Environment (CCME) Hazardous Waste Incineration Guidelines. The following section discusses each of those Guidelines and compares the standards within them with the USEPA standards for Hazardous Air Pollutants from Hazardous Waste Incinerators that were promulgated on September 30, 1999 (Reference 2). The specific control technology standards referred to in the Hazardous Air Pollutants from Hazardous Waste Incinerators, the Maximum Achievable Control Technology (MACT) Standards, are used as the basis for comparison with Canadian standards.

There are several background documents supporting the development of the MACT standards for hazardous Air Pollutants. These documents discuss the capability of the various alternative options for incineration and incineration air pollution control technologies. This documentation has been peer reviewed and is the most comprehensive and authoritative source of information on hazardous waste incineration and hazardous waste incinerator air pollution control technologies. Volumes 1, 3 and 4 of the MACT Standards are quoted extensively in this document and are cited at the end of this document in Section 6: References, and should be consulted in reading this document.¹

2.1 MOE A-7 Guideline for Municipal Incinerators

The first set of standards that the BEI system will meet is the MOE A-7 Guideline for Municipal Incinerators. There is no obligation for hazardous waste incinerators to meet the Ontario A-7 Guidelines. BEI's endorsement of the standards is voluntary.

¹ These references will be referred to as Reference 1, Reference 3, and Reference 4 in this report. For more information please consult: (<http://www.epa.gov/epaoswer/hazwaste/combust/index.html> and <http://www.epa.gov/epaoswer/hazwaste/combust/cmbust.htm>)

2.2 Canada Wide and CCME National Standards for Hazardous Waste Incinerators

BEI proposes to meet the Canada Wide Standard for Mercury and for Dioxins and Furans (PCDD/PCDF)² of 0.08 Ng I-TEQ/Rm³ which were accepted in principle by ministers on June 5-6, 2000. BEI will also meet the CCME's National Guidelines for Hazardous Waste Incineration Facilities.

2.3 USEPA MACT Standards

The USEPA standards were developed (Reference 2) to "ensure that hazardous waste combustion is conducted in a manner adequately protective of human health and the environment". The US Maximum Achievable Control Technology (MACT) standards were based on measurements taken at over 100 hazardous waste incinerators.

There are different MACT standards for existing versus new sources. The MACT standards for existing sources "cannot be less stringent than the average emission control achieved in practice by the best performing 12% of all sources". The average emission achieved in practice at the best performing 12 % of facilities extrapolates into the control techniques used by the best 6% of sources (known as the "MACT pool"). For new sources, MACT standards cannot be less stringent than the emission control achieved by the best-controlled single source. Table 1 includes the EPA MACT values for new sources.

According to Table 1, The USEPA MACT standards and individual requirements are similar to the Canadian standards. Therefore, BEI intends to meet the Canadian standards, and in addition will adopt the US EPA standard for hydrocarbon (HC) concentration (of 10 ppmv). As will be discussed later in this document, attaining a HC concentration of less than 10 ppmv is an indicator of high destruction and removal efficiencies (DRE) and low (dioxin) emissions.

Table 1. Compendium of Incineration Standards

Parameter	MOE A-7 Guideline (Allowable Stack Gas Concentrations)	USEPA Hazardous Waste Incinerator Standards, New Sources	Canada Wide, and CCME Allowable Stack Discharge Limits from Hazardous Waste Incinerators	Proposed Parameter Used in design
Organic Matter	<100 ppmv as methane	Hydrocarbons, 10 ppmv as methane		<10 ppmv as methane
CO		100 ppmv	57 (10 minute rolling average) mg/Rm ³	57 (10 minute rolling average) mg/Rm ³
HCl	27 mg/Rm ³	21 ppmv	75 mg/Rm ³	27 mg/Rm ³
Dioxins/ furans (PCDD/ PCDF)	0.14 Ng I-TEQ/Rm ³	0.2 Ng I-TEQ/dscm	0.08 Ng I-TEQ/Rm ³	0.08 Ng I-TEQ/Rm ³

² http://www.ccme.ca/pdfs/backgrounders_060600/DF_Standard_June2000_E.pdf

Parameter	MOE A-7 Guideline (Allowable Stack Gas Concentrations)	USEPA Hazardous Waste Incinerator Standards, New Sources	Canada Wide, and CCME Allowable Stack Discharge Limits from Hazardous Waste Incinerators	Proposed Parameter Used in design
SO ₂	56 mg/Rm ³			56 mg/Rm ³
Particulate	17 mg/Rm ³	34 mg/dscm	20 mg/Rm ³	17 mg/Rm ³
Cadmium	14 µg/Rm ³			14 µg/Rm ³
Mercury	57 µg/Rm ³		50 µg/Rm ³	50 µg/Rm ³
Lead	142 µg/Rm ³			142 µg/Rm ³
NO _x	110 Ppmv, arithmetic average of 24 hours data.			110 Ppmv, arithmetic average of 24 hours data.
Low Volatile Metals (antimony, arsenic, beryllium, and chromium)		97 mg/dscm		*
Semi Volatile Metals (Cadmium and Lead)		24 mg/dscm		*

'R' is used to denote standard conditions of 101.3 kPa, 25°C, and 11% O₂.

US EPA reference conditions are 101.3 KPa, 20°C and 7% O₂

3 Incineration Technology Selection Rational

3.1 Primary Combustion Chamber (PCC)

According to the US EPA (Reference 1) "hazardous waste units operating in the US include rotary kilns, liquid injection incinerators, fluidized bed incinerators, and fixed hearth incinerators. The majority of the commercial incinerators are rotary kilns (14) but in addition there are three liquid injection, one fluidized bed, and four fixed hearth facilities operating in the US. Of 168 on-site facilities, there are approximately equal numbers of rotary kilns and liquid injection facilities, with a few additional fixed hearths and fluidized beds".

According to the US EPA (Reference 1, section 2.1.1) rotary kilns have the following advantages as hazardous waste incinerators. "[Rotary Kilns can] handle almost any conceivable waste form (e.g., bulk and containerized solids, sludges, slurries, bulk and containerized liquids, and less common wastes such as Department of Defense propellants, munitions, and nerve agents) as well as a variety of waste compositions (e.g., wide ranges of waste organics, halogens, heating values, and principal organic hazardous constituents (POHCs))".

As BEI's target market is contaminated solids, a rotary kiln is the most appropriate primary combustion chamber technology. For the reasons listed above, all of the waste oxidizers that BEI has built or operated have been rotary kiln based.

3.1.1 Kiln Firing

According to the USEPA (Reference 1), in a rotary kiln *"Wastes are heated by the primary flame, bulk gases, and refractory walls. Through a series of volatilization and partial combustion reactions, combustible fractions of the wastes are gasified. The solids continue to heat and burn as they travel down the kiln. Typically, solids retention time in the kiln is 0.5 to 1.5 hours, while gas residence time through the kiln is usually around 2 seconds. Waste feed to the kiln is controlled so that the waste contributes no more than 20% of the kiln volume. Flame/solids temperatures in the rotary kiln range from 1200 to 3000°F [650 to 1650°C]"*.

Rotary kilns may be fired in a co-current or counter-current mode. In the co-current design, wastes and auxiliary fuels are fed at the same kiln end (i.e., the waste and flue gas travel in the same direction). According to the USEPA (Reference 1), *"almost all hazardous waste rotary kiln incinerators are of the "co-current" design because they are better suited toward treating combustible solid wastes. Co-current designs provide for rapid ignition of the cold wastes and maximum gas residence time for the products of combustion and thus achieve the largest amount of volatile organic destruction in the rotary section"*. The major reason for operating in the co-current mode is the fuel economy that can be attained if treating high organic containing combustible solid wastes. The organics in the waste are evolved early in the process and reduce the need for supplementary fuels. Co-current designs are limited in the maximum achievable temperature in the solids bed; a significant limitation when treating solids contaminated with high boiling point compounds.

Counter current kilns are design to have maximum heat transfer between the combustion gases and the in process solid matrix. The advantage of counter current kiln is the maximum achievable temperature of the solid bed - a significant advantage when treating high boiling point waste types. As the majority of the waste proposed to be treated by BEI will be low heating value (low BTU containing), and certain solid wastes will contain high boiling point contaminants, the proposed Kirkland Lake facility will be designed to operate in the counter-current mode.

3.1.2.1 Burner Design

The burners to be utilized in the proposed BEI kiln will be commercially available burners specifically designed for rotary kiln duty. Flame geometry will be designed for maximum radiant heat transfer between the burner flame and the kiln solids. Fuel oxidation will be staged and with sufficient turbulence factors to efficiently combust the fuel and meet the standards outlined in Table 1.

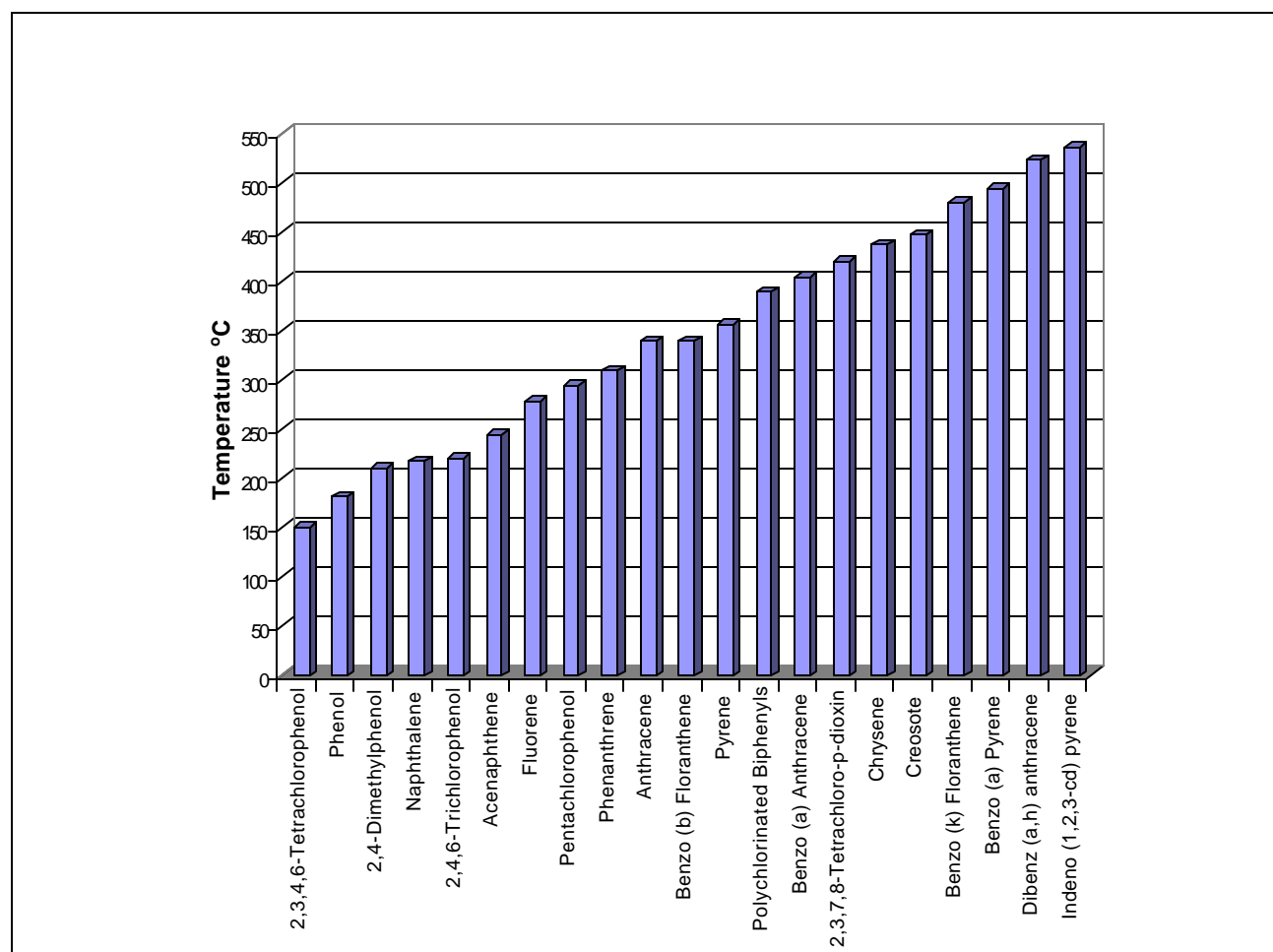
3.1.2.2 Temperature

Figure 1 outlines the boiling point for various organic species. The rotary kiln must heat the bed of solids to volatilize the species with the highest boiling. For example, if the feed solids are granular and contain primarily PCPs, minimum discharge temperatures of 350°C would be adequate to decontaminate the solids. However, if the solids are clay soil, the discharge temperature must be higher to ensure that temperature penetrated the soil ball adequately to drive out the contaminants. The degree of decontamination can be confirmed by analysis of decontaminated solids.

The design temperature for the kiln solids can be up to 900°C. However, the operating temperature to be utilized for a given type of waste will be customized to provide adequate desorption without utilizing excessive temperatures that would waste energy, generate excessive NO_x or potentially volatilize certain semivolatile metals such as lead and cadmium.

Figure 1 illustrates the boiling points of a number of potential organic contaminants. There are very few organic compounds with boiling points over 500°C. The design temperature of 900°C allows the rotary kiln to raise the solids temperature well above these boiling point temperatures.

Figure 1. Boiling Points of Organic Chemical Species



3.1.2.3 Seal Design

Seals will be installed at both ends of the kiln to limit the in leak of excess air to maintain negative pressures in the kiln.

3.1.2.4 Retention Time

The specifications for the proposed BEI kiln are described in Table 2.

Table 2. BEI PCC Process Parameters and Ranges

Parameter	Design
Decontaminated solids exit temperature	Max of 900°C. Actual temperatures would be based on contaminants in the soils
Solids retention time	24 to 600 minutes
Kiln Rotation Speed	0.1 to 2.5 RPM
Gas retention time	Greater than 3 seconds
Minimum oxygen content of kiln exhaust	3%
Fuel type	Natural gas, no. 2 fuel oil, tire-derived gas, waste derived fuel.
PCC gas Exit temperature	>600°C to a maximum of 1000 ° C depending on the waste being treated.
Pressure	
PCC	< - 0.25 (more negative) Cm H ₂ O

3.1.2.5 Monitoring of Kiln Exhaust

BEI proposes to measure the following parameters in the kiln exhaust on a continuous basis:

- Temperature of the decontaminated solids
- Temperature of the kiln exhaust gases
- O₂ content of the kiln exhaust gases
- Negative pressure inside the kiln at the burner end of the kiln

An in-situ oxygen probe will measure the kiln exhaust. With the feedback provided by the probe, operators will know and be able to control whether the kiln is being operated in either the reducing or oxidizing mode. Operation in the reducing mode at a sufficiently high temperature may volatilize and remove certain metals such as lead or zinc from the in process solids. The metals would condense in the Gas Conditioning Chamber and be removed from the gasses by the particulate removal device.

Operating in a reducing mode may convert certain metals from the oxide state to the metal state which may change their subsequent solubility when exposed to water. The treatment of high organic containing feeds in a oxygen deficient mode could produce a medium to low BTU gas to the SCC. The gas would reduce the need for auxiliary fuel inputs to the SCC. With a rotary kiln, there is the possibility of adding certain reagents to the feed that could convert potentially water-soluble inorganic species to less water-soluble inorganic species.

In summary, the important incinerator design parameters include retention time, temperature, burner design and seal design. BEI's proposed design will be state of the art for each of those parameters. The desorption efficiency for removal of organic compounds can be established by simply analyzing the organic content of the decontaminated kiln discharge. The level of organic compounds in decontaminated solids will be measured against the levels in the MOE *Guideline for Use at Contaminated Sites in Ontario* to determine post treatment disposal options. In addition, Ontario Regulation 558/00 (revision of O. Reg. 347) will be considered for site clean-up in Ontario.

3.2 Secondary Combustion Chamber (Afterburner) Design

The USEPA (Reference 1) makes the following points in discussing the secondary combustion chamber. "Exhaust gas from the kiln is usually routed to a secondary refractory lined combustion chamber, referred to as an 'afterburner'. The afterburner is typically operated at 2000 to 2500°F [1093-1371°C], with 100 to 200% excess air, turbulent mixing flow, and a gas residence time from 1 to 3 seconds to ensure complete combustion of the remaining volatile gas phase unburned components in the kiln flue gas. An auxiliary fuel, and sometimes pumpable liquid hazardous waste³, are used to maintain the afterburner temperature. A hot cyclone may be positioned between the kiln and afterburner for removal of entrained solid particles that may cause slagging⁴ problems in the afterburner".

Table 3 contains the CCME design and operating conditions for secondary combustion chambers. The CCME endorses higher Secondary Combustion Chamber temperatures for chlorinated and polynuclear materials. It is BEI's experience for certain solid feeds that operating temperatures exceeding 1000°C may result in excessive slagging that requires frequent shutdowns to manually clean slag buildups in the SCC.

Table 3. SCC (Afterburner) Design and Operating Conditions

Parameter	CCME National Guidelines for Hazardous Waste Incineration Facilities - Design	CCME Operating Guidelines	Specification for BEI Kirkland Lake
Gas residence time	2 seconds		Design >2.25 seconds
Temperature for chlorinated or polynuclear materials:	1300°C	1200°C	Design 1300°C Operating temperature to be established in the Certificate of Approval
Temperature for other organic materials	1100°C	1000°C	To be established during source testing (test burn)
Minimum oxygen content in flue gases at stack		3 %	3 %

The temperatures in the SCC must be sufficient to oxidize the organic chemical of concern.

The Incinerability Index⁵ (Appendix I) ranks organic chemicals by thermal stability. The most difficult to destroy compounds are at the top of the list. Compounds further down the list become progressively easier to destroy.

³ BEI may use Liquid Waste Derived Fuel (As defined by the Ontario MOE) or tire derived fuel as an auxiliary fuel, but will not treat liquid hazardous waste at the Kirkland Lake Facility.

⁴ Slagging is a build up of high-silica particulate on the walls of the SCC. The high temperatures can melt this buildup forming a semi-molten glass slag.

⁵ This index, obtained from Dr. Phillip H. Taylor of the University of Dayton Research Institute, is the most recent revision of the list originally published in the 1990 paper: *Development of a Thermal Stability Based Ranking of Hazardous Organic Compound Incinerability*. This list was created by the University of Dayton Research Institute and the US Environmental Protection Agency Risk Reduction Engineering Laboratory.

The Incinerability Index was derived from lab experiments, and theoretical calculations. One of the uses for the Incinerability Index is that if the destruction and removal efficiency (DRE) for a chemical substance is determined during a trial burn, it can be scientifically predicted that the DRE for all substances below that surrogate on the Incinerability Index would also meet that same or higher DRE.

It is BEI's intent to establish >99.9999% (six nines) DRE for chlorobenzene in a test burn (source test). Achieving this DRE for chlorobenzene would mean that the DRE for all chemical substances below chlorobenzene in Appendix I would also be greater than 99.9999 % (six nines).

The USEPA standard for hazardous waste incinerators is a DRE of >99.99% (four nines) for hazardous waste not including PCBs, Dioxins and Furans. Kilns that may receive PCB and dioxin/furan based wastes must attain a DRE >99.9999% (six nines). BEI's proposed kiln will be designed to meet the more rigorous six nines destruction standard.

DREs increase with increasing afterburner temperatures (Reference 4). The DRE for chlorobenzene indicates that an afterburner temperature of 1350°K [1077°C] is adequate for chlorobenzene (Reference 4).

A disadvantage of higher afterburner temperatures and increased turbulence is the offsetting production of NO_x. The priority is to maximize destruction of waste and the minimization of Hazardous Air Pollutants (HAPs), but a consideration in the combustor and burner design is to not produce excessive NO_x levels.

Therefore, it is BEI's intention to design the afterburner to meet the CCME design guidelines for temperatures listed in Table 3.

3.2.1 Confirmatory Stack Testing

Yearly DRE source testing is proposed for the facility. As mentioned above, chlorobenzene is the target surrogate for DRE testing. Testing of a system very similar to that proposed by BEI has demonstrated >99.9999% (six nines) DRE for chlorobenzene at a temperature of 1726 to 1741°F [941-950°C]⁶. The US EPA has no policy on minimum afterburner temperatures other than requiring that the minimum secondary combustion operating temperature be no less than what is utilized during the test burn.

BEI proposes that the USEPA practice of setting the minimum secondary combustion chamber temperature during the test burn be followed at the proposed Kirkland Lake facility.

3.2.2 Non Dioxin/Furan Organic Emissions

Emissions of hazardous organic compounds (other than Dioxins and Furans) are possible from two potential sources:

- undestroyed organic compounds fed to the combustor; or
- partial breakdown byproducts of incomplete combustion (PICs).

The following three subsections evaluate the control and monitoring of these compounds.

⁶ IT Corporation Times Beach trial burn conducted Nov. 1995.

3.2.2.1 Undestroyed HAPs Emitted from the Combustor

The USEPA summarizes DRE, HC and CO measurements at different hazardous waste incinerators (Reference 4, Table 5-1). According to the USEPA (Reference 4) "*the HC and CO stack concentrations are highly correlated with destruction efficiencies for all non dioxin HAPs*". The USEPA states, "*at CO levels of less than about 100 ppmv, there is no apparent relationship between CO and HC, except that when CO is low, HC levels are almost always low as well*".⁷

This supports the position that CO is usually a very conservative indicator for assuring good combustion conditions. However, there are cases for certain types of incinerators where CO can be high while HC levels are low, as discussed further below. Based on these considerations, compliance for non-PCDD/PCDF organic HAPs may be demonstrated by meeting either the CO or HC MACT standard on a continuous basis through the use of continuous emission monitoring.

According to the USEPA (Reference 4), high DREs for hazardous waste incinerators can be attained by: "*maintaining good combustion design, operating, and maintenance practices (GCP-D/O/M), some of which may include:*

- *Stoichiometric fuel/air ratio -- Providing adequate excess oxygen with use of oxygen CEM [Continuous Emissions Monitor] and feedback air input control.*
- *Combustion air distribution -- Providing adequate fuel and air mixing*".

The design to be utilized by the proposed BEI Kirkland Lake plant will target the above conditions. The proposed facility will be designed to attain a stack HC content of less than 10 ppmv.

3.2.2.2 Influence of Average Yearly Feed Concentrations on Undestroyed HAPs Emitted from the Combustor

Stack emissions are a function of the feed concentration multiplied by the destruction reduction efficiency attained. The proposed afterburner for the Kirkland Lake facility will be designed to meet >99.9999% (six nines) destruction for chlorobenzene, and >99.999% (five nines) DRE for naphthalene and other Poly-aromatic Hydrocarbons (PAHs).

BEI will limit the average yearly waste solids feed concentrations to relatively low values in order to minimize the health risk exposure to the community. Feed limits will be developed in conjunction with the Risk Assessment for the facility.

3.2.2.3 Monitoring and Control of Emissions of Partial Breakdown Byproducts of Incomplete Combustion (PICs)

According to the USEPA (Reference 4), "*CO/HC are well-demonstrated surrogate indicators for maintaining combustion efficiency, ensuring overall reaction completeness, and limiting the formation and emission of PICs. HC is a direct indicator of inefficient combustion and PIC emissions. The relationship between HC and certain PICs may not be as strong in cases where the HC is comprised mostly of lighter organic non-HAP compounds such as methane. However, there still remains a direct relationship, as demonstrated in tests including those referenced for HC*".

⁷ Reference 4, page 5-1.

BEI will perform continuous emission monitoring in the stack for both CO and HC. The operation of the plant to meet the MACT hydrocarbon standard of 10 ppmv will minimize the formation of PICs.

3.2.3 DRE During Upsets

The rotary kiln is extremely robust in being able to meet the target hydrocarbon (HC) levels. The following quotation illustrates this in a study where the researchers purposely attempted to create “worst case” hydrocarbon emissions:

"Attempts were made on a commercial rotary kiln incinerator to generate HC emissions greater than 5 ppmv... This involved various procedures to intentionally disrupt the combustion process, including modifying the degree of liquid waste atomization, operating at both very high and very low levels of excess oxygen, varying waste feed rates, varying combustion temperatures, water quenching portions of the incinerator, etc. However, with respect to HC emissions, the incineration process was extremely robust, and it was not possible to reasonably generate HC emissions greater than 3 ppmv." (Reference 3, page 5-9)

3.2.4 SCC - CEM Monitoring

BEI proposes to measure the following SCC parameters to limit non dioxin/furan HAP emissions:

- Temperature of the SCC exhaust
- O₂ content in the stack
- HC content in the stack
- CO content in the stack

3.2.5 Summary of Environmental Systems to be Incorporated into Proposed BEI SCC

There are a number of environmental systems to be incorporated into the proposed BEI secondary combustion chamber. The following factors must be considered in choosing such a system:

- Good combustion design, operating, and maintenance practices
- Stoichiometric fuel/air ratio -- Providing adequate excess oxygen with use of oxygen CEM and feedback air input control.
- Tangential combustion air distribution to provide superior mixing
- Continuous emissions monitoring for HC, CO and O₂
- Minimum SCC temperatures for each solids category
- Meeting CCME design guidelines
- Limiting feed concentrations of hazardous compounds.

4 Dioxin (PCDD/PCDF) Control

There are three mechanisms responsible for PCDD/PCDF emissions from the proposed BEI facility:

- fugitive emissions from PCDD/PCDF containing materials
- undestroyed PCDD/PCDF fed to the combustor

- low-temperature catalytic formation from PCDD/PCDF precursors such as polychlorinated biphenyls, benzenes, phenols, and other products of incomplete combustion (PICs). (This process is sometimes referred to as de-novo synthesis.)

Each mechanism is discussed below.

4.1 Fugitive Emissions and Stack Emissions of Undestroyed PCDD/PCDFs Fed to the Combustor

As shown in Appendix I, all of the PCDD/PCDFs are below chlorobenzene on the Incinerability Index. BEI proposes to establish >99.9999% (six nines) DRE for chlorobenzene. Chlorobenzene destruction becomes the surrogate that will prove that six nines PCDD/PCDF destruction can also be established.

As part of the environmental assessment process, BEI will develop a table listing the maximum average yearly concentration of PCDD/PCDF that will be fed to the proposed thermal unit. This table will also lists the resultant average yearly emission of PCDD/PCDF based on DRE and the resultant fugitive emissions from handling feed materials contaminated with PCDD/PCDF.

Controls for fugitive PCDD/PCDF emissions include activated carbon injection into the duct to form a precoat ahead of the ventilation fabric filtration system⁸.

With reference to the previous discussion on minimizing HAP emissions in Section 3.2.2, the USEPA states:

"the monitoring of HC and the continuous monitoring and control of certain products of incomplete combustion may provide further assurance of good combustion practices and control of PCDD/PCDF emissions " (Reference 4).

4.2 Low-Temperature Catalytic Formation of PCDD/PCDF from Precursors and Products of Incomplete Combustion (PICs)

The USEPA has researched PCDD/PCDF control in great depth. Their emphasis has been on developing an understanding of how to minimize the generation of dioxins. BEI endorses this approach.

MACT PCDD/PCDF standards can be met totally by utilizing techniques that minimize the formation of dioxins. No PCDD/PCDF removal techniques are required to meet the standards. The following section discusses USEPA know-how on minimizing the formation of dioxins in hazardous waste incinerators.

"PCDD/PCDF can be formed through a low-temperature catalytic formation process, typically occurring as the combustion gas is cooled and/or passed through a "dry" PM [Particulate Matter] control device. In order for the PCDD/PCDF to form, there must be precursors. Therefore, PCDD/PCDF formation can be minimized by Maintaining good combustion conditions by limiting the generation of potential PCDD/PCDF formation precursors such as polychlorinated biphenyls, benzenes, phenols, and other products of incomplete combustion (PICs). Good combustion is maintained on a real-time basis through the monitoring and control of hazardous waste feed rate, hazardous waste composition, combustion temperature, CO and HC combustion gas levels, etc". (Reference 4, section 3.2)

⁸ Details of the filtration system will be included with the BEI Application for a Provisional Certificate of Approval for a Waste Disposal Site to be located at 233 Archer Drive, Kirkland Lake Ontario.

EPA has also advised that *"Formation due to this mechanism has been shown to be attributable to factors including:*

Gas temperature at the inlet of dry PM APCD [Air Pollution Control Device]-- A limit on maximum gas temperature at the inlet of "dry" PM APCDs is required. "Dry" PM APCDs include ESPs [Electrostatic Precipitators] and FFs [Fabric Filters], which typically operate at temperatures from 300 to 500°F [150-260°C], and at a minimum, levels comfortably above the flue gas dew point (which typically ranges from 120 to 200°F [50-93°C]).

This limit is not generally applicable to certain dry PM devices such as cyclones and other inertial type collectors where the PM is not suspended in the gas stream for great lengths of time, making the formation of PCDD/PCDF not as likely in these devices compared with FFs and ESPs.

Determination of the requirement for maximum temperature limits on other types of dry PM control devices is made on a site-specific basis depending on gas residence time in the control device, nature of the particulate hold up in the device, operating temperature, etc. PCDD/PCDF can be formed through a low-temperature catalytic formation process, typically occurring as the combustion gas is cooled and/or passed through a "dry" PM control device.

Formation due to this mechanism has been shown to be attributable to factors including:

- (1) combustion gas quenching rate (gas temperature and residence time profile);*
- (2) PM control device temperature; and*
- (3) composition of the entrained PM, in particular its catalytic metals content.*

Gas temperature at the inlet of dry PM APCD -- A limit on maximum gas temperature at the inlet of "the dry" PM APCD is required". (Reference 4)

BEI proposes to utilize a dry fabric filter device for particulate removal. The alternatives to fabric filters for particulate control will be discussed later in this document. According to the Federal Register (Reference 2), if the temperature at the inlet to the fabric filter is limited to below 400°F [204°C], *"post-combustion formation is reasonably minimized at temperatures of 400°F [204°C] or below".* Reference 4.

The maximum inlet temperature to the proposed BEI fabric filter unit will be set at 160°C.

5 Air Pollution Control Technologies

5.1 Particulate Control

As cooling to 400°F [204°C] is necessary to meet PCDD/PCDF criteria, the following hazardous air pollutant metals will be removed if present as a particulate in the flue gases:

- Low Volatility Metals (LVM), (antimony, arsenic, beryllium, and chromium),
- Semi-Volatile Metals (SVM) (lead and cadmium)
- HAP metals (cobalt, manganese, nickel, selenium)
- HAP organics that condense at less than 400°F [204°C].

"The MACT pool is comprised of 5 sources (6% of all sources in the database). All MACT pool sources control PM to less than 0.001 gr/dscf on average. MACT is defined by the use of the following PM APCDs:

- FF with air-to-cloth ratio less than 10 acfm/ft² (based on source 350C3).
- IWS [Ionizing Wet Scrubbers] and VS [Venturi Scrubbers] (based on source 354C1). ESP is considered as equivalent technology". (Reference 3)

The MOE A-7 Guideline limits particulate emissions to 17 mg/Rm³. Typically this level requires a fabric filter.

5.1.1 Ionizing Wet Scrubbers (IWS)

Ionizing Wet Scrubbers (IWS) can be utilized for particulate removal, however, BEI has not selected IWS for the following reasons:

- Ionizing wet scrubbers must usually be staged to meet particulate requirements.
- Wet sludges are produced which must be dewatered. The dewatering costs are significant and complicate the flow sheet.
- The water flow sheet for an IWS is complex, as the IWS needs a higher quality feed water than a venturi scrubber.
- Higher volumes of water are required for wet scrubbers than for dry type cleaning devices.
- Salt solutions are produced with wet scrubbers that are more difficult to dewater and dispose of than the dry powders produced by dry scrubbers.
- The proposed facility is designed to operate in winter conditions and could result in freezing of the scrubber water.

5.1.2 High Energy Wet Scrubber

High Energy Venturi Scrubbers can be utilized for particulate removal, however, BEI has not selected High Energy West Scrubbers for the following reasons:

- Extremely high pressure drops must be utilized to obtain the equivalent gas cleanliness obtained from a fabric filter installation (>10 mg/dscm).
- Noise starts to be a potential problem with high pressure drop fans.
- The wet scrubber will saturate the gas and produce a much more visible steam plume. The size of the plume is a function of the stack exhaust temperature. The stack exhaust temperature from a wet scrubber will be about 80°C versus a stack exhaust temperature of about 140°C from a fabric filter installation. A 80°C plume will be visible most of the year whereas a 140°C plume will generally not be visible during summer months.

5.1.3 Dry Electrostatic Precipitators

Dry Electrostatic Precipitators (ESP) can be utilized for particulate removal, however, BEI has not selected dry ESP for the following reasons:

- Energy utilization is high.
- ESP's operate in a temperature range conducive to the formation of PCDD/PCDF.

5.1.4 Fabric Filters

BEI has selected Dry Fabric Filters for particulate control. The benefits of Fabric Filters are:

- Increased capture efficiency and sorbent utilization compared with Electrostatic Precipitators (ESPs).
- The captured sorbent and fly ash is held on the fabric and remains exposed to the flue gas, thus allowing for further reaction of the unused sorbent with the flue gas in the particulate collector.
- Ease of operation and maintenance.
- Simplicity and Reliability.
- Dry collected residue (spent reagents & collected dust)

BEI will employ a fabric filtration device with an air-to-cloth ratio less than 4 acfm/ft² as it can attain the lowest particulate exhaust levels. BEI will also utilize dry scrubbing for HCl control and carbon injection for mercury and PCCD/PCCF control in conjunction with the fabric filter particulate control.

5.2 PCDD/PCDF Removal Technology

5.2.1 Activated Carbon Injection

Carbon injection may be used for PCDD/PCDF control. *"This can be achieved using carbon beds or by injecting carbon and collecting it in a downstream PM APCD. ... Effectiveness is determined by parameters including carbon injection rate, carbon type and specifications, carbon-to-gas mixing, carbon reuse rate, and carbon injection temperature"* (Reference 3). In addition, to obtain satisfactory removal efficiencies, *"A limit on the minimum carbon injection rate is required."* (Reference 4) ⁹

BEI proposes to utilize carbon injection ahead of the fabric filter as a supplemental dioxin control technology for the proposed Kirkland Lake facility. It is proposed that the minimum carbon injection rate be established in the Certificate of Approval.

Carbon is injected in the dry scrubber ahead of the fabric filter at BEI's Récupère Sol Inc. (RSI) facility in Quebec. Stack emissions are consistently below the proposed Canada Wide Standard for dioxin of 0.08 ng I-TEQ/ Rm³ at RSI.

5.2.2 Catalytic Oxidizer

Catalytic oxidizers are another option for PCDD/PCDF control.¹⁰ Flue gas temperature and flow rate, catalyst age, catalyst type, and flue gas CO, HC, or PIC constituent levels may be indicators of catalyst performance.

⁹ Rationale -- Increased rates of carbon injection lead to increased levels of PCDD/PCDF control.

Limit compliance period -- The minimum limit is complied with on a 1-hour rolling average period.

Limit basis -- The limit is set based on comprehensive performance test demonstrations.

The 1-hour limit is based on the average of the individual run averages (from each pertinent test run of the comprehensive performance testing)."

¹⁰ For a more detailed discussion, consult page 3-17, Reference 4.

BEI has chosen carbon injection over catalytic oxidation for supplemental PCDD/PCDF control as carbon injection has the advantage of high mercury removal rates (See section 2.8).

5.2.3 *The Alternative of Controlling Chlorine in the Feed to Limit PCDD/PCDF Formation*

"PCDD/PCDF formation has been shown to be sensitive to the chlorine content of the fly ash, and alternatively not very sensitive to the HCl content of the flue gas. Chlorine saturation in the fly ash occurs at low levels of chlorine in the feed. At higher chlorine feed levels, the HCl gas content increases proportionally, with no effect on the fly ash chlorine content.

Thus PCDD/PCDF formation is not significantly impacted by higher chlorine levels. Note that PCDD/PCDF can be formed when burning very low chlorine-containing wastes. Dow reports detecting PCDD/PCDF at a level of 20 ng/dscm total PCDD/PCDF, (not TEQ) when burning chlorine-free distillate oil. PCDD/PCDF has been found in diesel [and] gasoline engine exhaust, at a level of 5.4 ng TEQ/kilometer.

Chlorine contained in the combustion air has been attributed to PCDD/PCDF formation. Inland ambient air can contain 1 to 10 ppb chlorine. The chlorine content of air near the ocean can approach 1 ppm. Thus, ambient air may have from 100 to 100,000 times more chlorine than is theoretically needed to form PCDD/PCDF at a PCDD/PCDF level of 20 ng/dscm (total PCDD/PCDF, not TEQ)." (Page 3-11, Reference 4).

5.2.4 *The Utilization of Particulate Control Devices for Controlling Dioxin Emissions*

In conclusion, the combination of an advanced combustion system that will minimize the availability of PCDD/PCDF precursors and the utilization of activated carbon injection will allow the proposed BEI plant to meet the Canada Wide Standard for PCDD/PCDF. To BEI's knowledge, this is the most stringent PCDD/PCDF standard in the world.

5.2.5 *Chlorine and HCl Control*

Chlorine and HCl can be controlled either with wet scrubbers, wet absorption towers or dry systems. Reagents used with smaller wet scrubbers or wet absorption systems are usually caustic based to avoid the clogging problems inherent with adding hydrated lime or limestone to water.

The utilization of caustic produces a more soluble end product but is more difficult to dispose of.

Dry scrubbing systems to control hydrogen chloride (HCl) are used on various types of combustors, including: medical waste incinerators (MWIs), municipal waste combustors (MWCs), hazardous waste incinerators (HWIs), and other types of combustion facilities such as coal, wood, and sewage sludge. According to Reference 5, three hazardous waste incinerators rely on dry scrubbing for acid gas control, Olin Chemicals, Glaxo, and Trade Waste Incineration.

"Dry and semi-dry scrubbers are typically not as efficient as wet scrubbers for chlorine control. However, based on limited performance on HWIs and comprehensive operation on MWIs [Medical Waste Incinerators], MWCs [Municipal Waste Combustors], and utility boilers, dry and semi-dry scrubbing systems can regularly achieve performance levels greater than 90% control efficiency and less than 25

ppmv outlet emissions. In many cases, greater than 99% control efficiency has been demonstrated with dry scrubbing systems". (Reference 3)

“Dry scrubbing” can generally refer to two types of related, but distinct, dry scrubbing arrangements:

- “Duct sorbent injection” (DSI) -- DSI involves the injection of a dry sorbent fine powder into the flue gas directly upstream of a particulate control device (in particular, a device which collects the particulate in a dry form, such as an FF or ESP). Acids in the flue gas react with the sorbent to form solid salts, which are removed in the particulate collector. The flue gas is cooled prior to the dry sorbent injection, usually to a level in the range of 300 to 400°F [150-204°C].
- “Spray dryer adsorption” (SDA) -- SDA is similar to DSI discussed above except that the sorbent is mixed with water to form a slurry solution that is injected into the duct. The system is designed so that the water is totally evaporated prior to particulate collection. SDA is considered a “semi-dry” process because a wet sorbent material is used, but the residue produced is dry.

The following factors influence Dry Scrubbing Performance:

- Temperature -- The flue gas-sorbent injection temperature and particulate control device temperature are critical to performance. Performance dramatically increases as the injection temperature approaches the acid gas dew point temperature (i.e., as the flue gas temperature decreases). The effect of temperature on performance is shown in Figure 14-6¹¹. Typical temperatures range from 260 to 350°F [127-177°C]. However, the process is limited to a lower minimum level of around 50°F [10°C] above the saturation temperature (about 250°F [121°C]) to avoid operational difficulties from corrosion and “wet and sticky” dust cakes that form at lower temperatures.
- Flue gas humidity -- Acid gas capture performance increases as the relative humidity increases. Many DSI arrangements (and all SDA systems) use humidification of the flue gas upstream of the dry sorbent injection to enhance the acid gas/sorbent reaction.
- Sorbent feed rate -- Performance increases as the sorbent-to-acid gas ratio increases, as also shown in Figure 14-6 and 14-7. Typically, 1.5 to 3 times the stoichiometric ratio of sorbent to acid gas is provided to achieve acid gas control levels of greater than 90%.
- Flue gas-sorbent mixing and contacting -- Performance increases as the mixing between the sorbent and flue gas increases. Many dry scrubbing arrangements use specially designed dedicated vessels and injectors to increase contacting degree and time, including venturi reactors, fluidized bed reactors, and co-current and counter-current reactors.

BEI utilizes a dry scrubber at the RSI plant. Hydrated lime is injected into the gas scrubber vessel after the conditioning tower and ahead of the fabric filter. BEI proposes to inject hydrated lime into the gas ahead of the fabric filter at the proposed Kirkland Lake project.

The major advantage of operating a dry scrubber is that the lime is converted to calcium chloride which is non-hazardous, and relatively easy to dispose of. Wet scrubbing systems produce liquid caustic or lime solutions that must be dewatered, precipitated and dried.

¹¹ Dhargalkar, P. K and J. T. Zmuda, 1989. *Dry Scrubbing Experience in Resource Recovery Applications*. Air and Waste Management Association, 82nd Annual Meeting, Anaheim, California, 1989.

Figure 14-6. HCl removal as a function of dry scrubbing stoichiometry

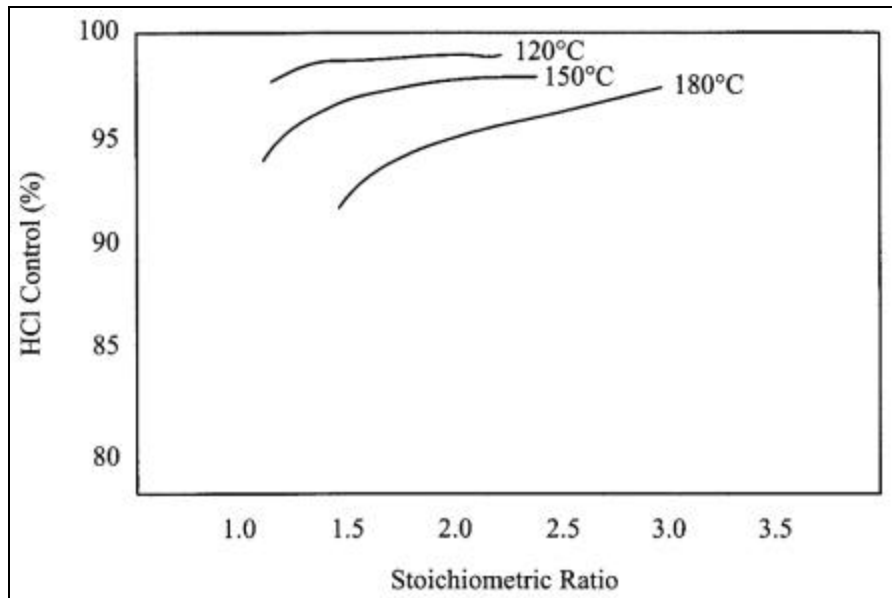
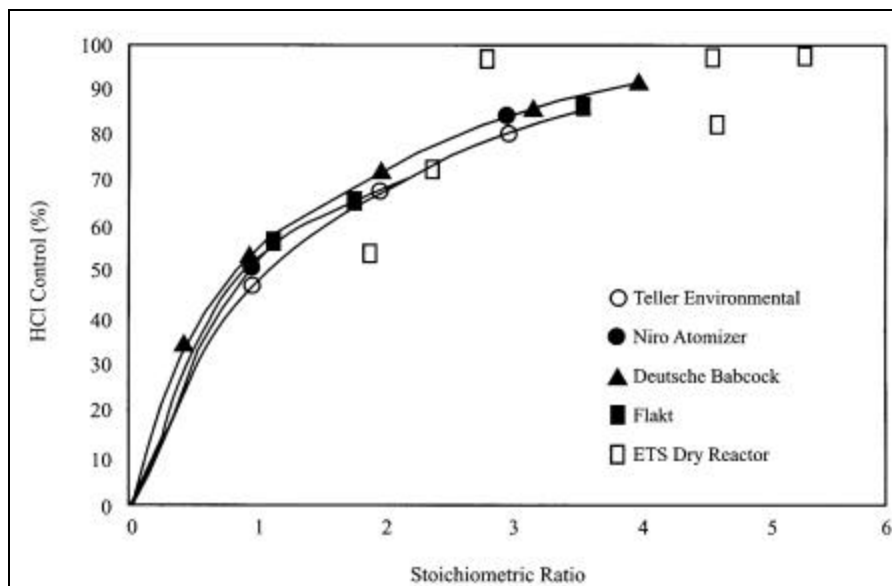


Figure 14-7. Impact of stoichiometry on dry scrubbing HCl control efficiency.



5.3 SO₂

SO₂ emissions will be controlled by the hydrated lime dry scrubbing system that will also remove HCl. An SO₂ continuous emissions monitor (CEM) has been proposed for the Kirkland Lake project. Low sulphur fuels will be utilized at the plant. The major source of SO₂ emissions will be pyrite or other reduced sulphur levels in the solid feed.

BEI will monitor the reduced sulphur content of incoming feeds and establish cut off levels.

5.4 NO_x

NO_x is a precursor to ozone or smog formation. Combustion modifications are the most popular and most economic means to meet NO_x targets. Close control of O₂ levels are often an excellent means of limiting NO_x emissions. NO_x will be controlled by utilizing low NO_x burners.

BEI proposes to install a NO_x CEM monitor.

5.5 Mercury

“Mercury emissions from existing HWIs are controlled through feed rate and/or use of air pollution control devices, including wet scrubbing and activated carbon adsorption”. Reference 3.

5.5.1 Wet Scrubbers

“Generally, existing HWI wet scrubber SREs [Scrubber Removal Efficiencies] range from 15 to 60% for conditions where active mercury spiking took place.” Reference 3

5.5.2 Activated carbon Adsorption and Feed Rate Control

“Activated carbon adsorption-based control methods are used on three sources (Reference 3). A carbon bed is used on one facility, Source ID No. 341, where it is difficult to assess its mercury control performance with available data. Carbon injection is used on Source ID No. 222 on a full time basis and on Source ID No. 601 on an experimental basis. Greater than 97% mercury control is being consistently demonstrated with carbon injection at these sources.” Reference 3.

Two methods of mercury control are being proposed for the BEI plant. The first method will be the feed control. Wastes containing mercury contents above predetermined levels will be rejected for treatment at the proposed BEI plant.

Low levels of mercury that may be evolved from the kiln will be removed by the activated carbon system to be installed at the proposed plant. The combination of feed control and activated carbon will be able to meet the CCME standards for mercury (Table 1).

6 References

Reference 1, Final Technical Support Document for HWC MACT Standards
Volume 1, Description of Source Categories

Reference 2, Federal Register, Thursday September 30, 1999, Final Standards for Hazardous Air
Pollutants for Hazardous Waste Combustors

Reference 3, Final Technical Support Document for HWC MACT Standards
Volume III

Reference 4, Final Technical Support Document for HWC MACT Standards
Volume IV:
Compliance with the HWC MACT Standards

Reference 5, Draft, Technical Support Document for HWC MACT Standards
Volume II

HWC Emissions Database
November, 1995

7 Appendix 1: Incinerability Index

The complete Incinerability Index is available from:

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The index can be viewed at offices of public record.