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Risk Burn Guidance for Hazardous Waste Combustion Facilities

ACKNOWLEDGMENTS

RISK BURN GUIDANCE
FOR
HAZARDOUS WASTE COMBUSTION
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ACRONYM LIST

μg/dL	Micrograms per deciliter
μg/m^3	Micrograms per cubic meter
APCD	Air pollution control device
ASME	American Society of Mechanical Engineers
ATSDR	Agency for Toxic Substances and Disease Registry
AWFCO	Automatic waste feed cutoff
BIF	Boiler and industrial furnace
Btu	British thermal unit
CEMS	Continuous emissions monitoring system
CFR	Code of Federal Regulations
Cl$_2$	Molecular chlorine
COPC	Compound of potential concern
CSF	Carcinogenic slope factor
D/F	Dioxin and furan
DQO	Data quality objective
DRE	Destruction and removal efficiency
dscm	Dry standard cubic meter
EDL	Estimated detection limit
EER	Energy and Environmental Research Corporation
EMPC	Estimated maximum possible concentration
EPA	U.S. Environmental Protection Agency
ESP	Electrostatic precipitator
FGC	Field gas chromatography
GC	Gas chromatography
g/cm^3	Grams per cubic centimeter
grains/dscf	Grains per dry standard cubic foot
GRAV	Gravimetric
HCl	Hydrogen chloride

ACRONYM LIST (Continued)

HEAST	Health Effects Assessment Summary Tables
HEPA	High efficiency particulate air
HRA	Hourly rolling average
IRIS	Integrated Risk Information System
IWS	Ionizing wet scrubber
MACT	Maximum achievable control technology
MDL	Method detection limit
mg/dscm	Milligrams per dry standard cubic meter
mg/kg	Milligrams per kilogram
MS	Mass spectrometry
ng	Nanograms
NAAQS	National Ambient Air Quality Standard
OSW	Office of Solid Waste
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCC	Primary combustion chamber
PIC	Product of incomplete combustion
POHC	Principal organic hazardous constituent
ppm	Parts per million
ppmv	Parts per million volume
QAPP	Quality assurance project plan
RAC	Reference air concentration
RCRA	Resource Conservation and Recovery Act
RDL	Reliable detection limit
RfC	Reference concentration
RfD	Reference dose
RME	Reasonable maximum exposure

RTI   Research Triangle Institute

SCC   Secondary combustion chamber

SQL   Sample quantitation limit

SRE   System removal efficiency

TCO   Total chromatographable organics

TEQ   Toxic equivalents

TIC   Tentatively identified compound

TOE   Total organic emissions

U/BK   Uptake/biokinetic

WESP   Wet electrostatic precipitator

CHAPTER 1

INTRODUCTION

This document contains the U.S. Environmental Protection Agency (EPA) Office of Solid Waste's (OSW's) recommendations regarding stack emissions tests which may be performed at hazardous waste combustion facilities for the purpose of supporting multi-pathway, site-specific risk assessments, where such a risk assessment has been determined to be necessary by the permit authority. When a site-specific risk assessment will be performed as part of the Resource Conservation and Recovery Act (RCRA) permit decision for a hazardous waste combustion facility, the supporting emissions data may be collected in conjunction with a RCRA trial burn. The emissions data may also be collected during a test event separate from the RCRA trial burn, such as a Maximum Achievable Control Technology (MACT) performance test or other test. This guidance identifies the types of emissions data that EPA OSW recommends be collected to support site-specific risk assessments. The guidance recommends combustor operating and feed conditions that should generally be demonstrated during the testing, and identifies stack sampling and analytical techniques for collection of the emissions data. In addition, the relationship between test conditions and potential RCRA permit conditions is discussed.

Hazardous waste combustors include hazardous waste incinerators, as well as boilers and industrial furnaces (BIFs) that burn hazardous waste for energy or material recovery. Portions of this guidance may also be useful for emissions test efforts at thermal treatment facilities (other than incinerators and BIFs) conducting multi-pathway, site-specific risk assessments, as determined appropriate under 40 Code of Federal Regulations (CFR) Sections 264.601 and 264.602.

Multi-pathway human health and ecological risk assessments may be performed for hazardous waste combustion facilities to assess potential risks associated with direct and indirect exposures to:

C   Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, known collectively as dioxins and furans (D/Fs);

C   Organic emissions (volatile, semivolatile, and nonvolatile) other than D/Fs, often referred to as products of incomplete combustion (PICs);

C   Metals that are potentially toxic to human or ecological receptors;

C   Hydrogen chloride (HCl) and molecular chlorine (Cl_2);

(EPA 1998a, 1999a and 1999b). Direct exposures include exposures via the inhalation pathway (EPA 1998a). Indirect exposures include exposures from contact of human and ecological receptors with soil, plants or waterbodies on which an emitted chemical has been deposited, resulting in bioaccumulation and food chain effects (EPA 1998a).

Performance of a site-specific risk assessment can provide the information necessary to determine what, if any, additional conditions in the RCRA permit may be necessary for each situation to ensure that operation of the combustion unit is protective of human health and the environment (EPA 1998a). These additional conditions may include, for example, emissions limits (such as limits on D/Fs, metals, or other site-specific compounds), process operating conditions, waste feed limitations, or expanded environmental monitoring (EPA 1998a).

1.1   USE OF THIS DOCUMENT

This document contains EPA OSW's recommendations regarding stack emissions tests which may be performed at hazardous waste combustion facilities for the purpose of supporting multi-pathway, site-specific risk assessments. This document does not provide recommendations regarding whether a site-specific risk assessment should be performed for a particular hazardous waste combustion facility, nor is it intended to provide guidance about how to conduct a site-specific risk assessment or make risk management decisions. It is recommended that users of this document consult other documents regarding risk assessment and risk management issues. The preamble to the hazardous waste combustion MACT rule published on September 30, 1999 (64 *Federal Register* 52828) contains EPA's most recent recommendations regarding when or if a site-specific risk assessment should be considered. EPA OSW

guidance for how to conduct a multi-pathway human health and ecological risk assessment is available in peer review draft form (EPA 1998a, 1999a, 1999b). And, EPA OSW's recommended risk and hazard targets that may be used when making risk management decisions are provided in an earlier guidance (EPA 1994a). Additional risk target information is also available (EPA 1998b). Many of the recommendations included in the MACT rule preamble and the human health/ecological risk assessment documents are also identified in this document for the convenience of the reader. However, this document is not intended to update, revise or replace the information contained in those documents. Revisions to the human health and ecological risk assessment documents are in progress, and more recent versions should be consulted when available. Other combustion risk assessment guidance (e.g., Research Triangle Institute [RTI] 1997) may also be consulted.

This document updates and replaces the following guidance documents related to emissions testing which may be performed for the purpose of supporting multi-pathway, site-specific risk assessments:

- C U.S. EPA. *Guidance on Trial Burns.* June 2, 1994 Draft.

- C U.S. EPA. *Guidance on Structuring RCRA Trial Burns for Collection of Risk Assessment Data.* May 2, 1997 and September 1997 Drafts.

- C U.S. EPA. *Guidance on Collection of Emissions Data to Support Site-Specific Risk Assessments at Hazardous Waste Combustion Facilities*. Peer Review Draft. EPA530-D-98-002. August 1998.

This guidance is not intended to update, revise or replace any RCRA or MACT regulatory requirements pertaining to stack emissions testing, or the guidance documents which have been developed to support implementation of those requirements. Examples of guidance documents which are not superseded include:

- C U.S. EPA. *Handbook: Guidance on Setting Permit Conditions and Reporting Trial Burn Results. Volume II of the Hazardous Waste Incineration Guidance Series.* Office of Research and Development. EPA/625/6-89/019. January 1989.

- C U.S. EPA. *Handbook: Hazardous Waste Incineration Measurement Guidance Manual. Volume III of the Hazardous Waste Incineration Guidance Series.* Office of Solid Waste and Emergency Response. EPA/625/6-89/021. June 1989.

C   U.S. EPA. *Handbook: Quality Assurance/Quality Control (QA/QC) Procedures for Hazardous Waste Incineration.* Office of Research and Development. EPA/625/6-89/023. January 1990.

C   U.S. EPA. *Technical Implementation Document for EPA's Boiler and Industrial Furnace Regulations.* Office of Solid Waste and Emergency Response. EPA-530-R-92-011. March 1992.

C   U.S. EPA. *Final Technical Support Document for Hazardous Waste Combustor MACT Standards, Volume IV: Compliance with the MACT Standards.* Office of Solid Waste and Emergency Response. July 1999.

This document provides guidance to EPA regional and state permitting authorities on how best to implement statutory and regulatory provisions that concern permitting decisions for hazardous waste combustion facilities under the RCRA program. In particular, this document provides guidance regarding activities carried out pursuant to RCRA § 3005(c)(3), the "omnibus" authority, as codified in 40 CFR § 270.32(b)(2) and 40 CFR § 270.10(k). For EPA's explanation of the Agency's authority to carry out, or require, these activities, please refer to EPA OSW's guidance for how to conduct multi-pathway human health and ecological risk assessments (EPA 1998a and 1999a) and the preamble to the hazardous waste combustion MACT rule (EPA 1999c). This document is not intended to provide any new interpretations regarding the "omnibus" authority or any other statutory or regulatory authority, nor is it intended to reopen for consideration any statutory or regulatory interpretation in the risk assessment guidance documents (EPA 1998a and 1999a), the preamble to the MACT rule (EPA 1999c), or any other document.

This document describes statutory provisions and EPA regulations which are legally binding requirements. It does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on EPA, States, or the regulated community. Any decisions made regarding a particular facility will be made based on the statute and the regulations. EPA and State regulatory authorities retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance. Therefore, interested parties are free to raise questions and objections about substance of this guidance and the appropriateness of any recommendations in the guidance with respect to a particular situation, and the regulatory authorities will consider whether or not the recommendations in the guidance are appropriate in that situation. This guidance is a living document, and may be updated without public

notice. EPA OSW welcomes public comments on this document at any time and will consider those comments in any future revision of this document.

1.2   OBJECTIVES

The objectives of this guidance are to:

1. **Provide recommendations to ensure the collection of adequate data to support completion of technically sound human health and ecological risk assessments.** Specific risk assessment data needs generally include: (1) D/F emission rates, (2) emission rates for organics other than D/Fs, (3) metals emission rates, (4) site-specific particle-size distribution data, and (5) emission rates for HCl and Cl_2. These data needs are discussed in detail in Chapter 2, and sampling and analytical procedures are discussed in Appendix B.   Other risk assessment data needs can be addressed on a site-specific basis, and can include compounds such as radionuclides or other criteria pollutants not specifically addressed in this guidance. Additional discussion of these other compounds can be found in the EPA OSW risk assessment guidance (EPA1998a).

2. **Identify considerations associated with selection of appropriate test conditions for collection of emissions data supporting a site-specific risk assessment.** The emissions data to support a site-specific risk assessment may be collected in conjunction with a RCRA trial burn or a MACT performance test, where "worst-case" operating conditions are targeted to maximize emissions. It may also be appropriate to collect the emissions data during a separate test conducted exclusively for collection of risk assessment data, where the combustor might be operated under conditions representing long-term average, or normal, operations. Selection of appropriate test conditions for collection of risk assessment data is discussed in detail in Chapter 3.

3. **Identify key control parameters that may influence emissions of D/Fs, organics other than D/Fs, metals and HCl/Cl₂.** Feed and operating control parameters that should generally be demonstrated during the emissions testing and which may be limited by the final permit are identified and discussed. This guidance also identifies inherent design differences between hazardous waste burning incinerators, boilers, cement kilns, and lightweight aggregate kilns, and accounts for these differences in recommending control parameters to be limited under RCRA. Key control parameters related to emissions of D/Fs, organics other than D/Fs, metals, and HCl and Cl_2 emissions are discussed in Chapters 4, 5, 6, and 7, respectively. Particle-size distribution is discussed in Chapter 7.

4. **Provide recommendations regarding how to report emissions data and how to evaluate various emission scenarios in the risk assessment.** These issues are discussed in Chapter 8, and are illustrated by the examples in Appendix A.

5. **Identify additional permit terms that may be included in the final RCRA permit based upon evaluation of the risk burn results and risk assessment.** These issues are discussed in Chapters 3

through 9, and are illustrated by the examples in Appendix A.

Although general guidelines are provided, this guidance cannot encompass every potential situation. Permit writers are encouraged to consider facility-specific circumstances that may not be fully addressed.

1.3   REGULATORY REVIEW

This section provides summary information to explain how emissions tests and risk assessments factor into the RCRA regulatory framework for hazardous waste combustion facilities. First, background information on RCRA performance standards and trial burns is provided. Potential limitations of the RCRA regulations are identified, and the use of site-specific risk assessments to supplement those regulations is discussed. Finally, MACT standards for hazardous waste combustion facilities (EPA 1999c) are introduced briefly, and the relationship between the MACT standards and site-specific risk assessments is explained. This review is minimal and provided only for the convenience of the reader. Cited references should be consulted. Terms are defined in Section 1.4.

1.3.1   RCRA Performance Standards and Trial Burns

Performance standards for hazardous waste incinerators are described in Title 40 of the Code of Federal Regulations (CFR) Part 264, Subpart O. These standards were promulgated on January 23, 1981, and have been subsequently amended. The performance standards consist of the following: (1) a destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs) of 99.99 percent, or 99.9999 percent for dioxin-listed wastes; (2) particulate matter emissions not to exceed 180 milligrams per dry standard cubic meter (mg/dscm) or 0.08 grains per dry standard cubic foot (grains/dscf), corrected to 7 percent oxygen; and (3) gaseous HCl emissions not to exceed 1.8 kilograms per hour or a removal efficiency of 99 percent. Compliance with these performance standards is generally established through a carefully designed trial burn (see 40 CFR § 270.62). Trial burns are typically conducted at extreme "worst-case" operating conditions of the unit in order to define the maximum operating range (or operating envelope) that assures compliance. Testing at "worst-case" conditions generally involves at least one

performance test condition conducted at a minimum combustion temperature to demonstrate DRE. Additional test conditions may be necessary to resolve potential conflicts between operating parameters. As long as the incinerator continues to operate within the operating envelope demonstrated during a successful trial burn, it is presumed to be in compliance with the regulatory performance standards.

Ongoing compliance with the three performance standards is generally assured by developing limits for the following control parameters, as specified in 40 CFR § 264.345:

C   Minimum combustion temperature in the primary combustion chamber (PCC) and secondary combustion chamber (SCC), to assure sufficient temperatures for destruction of organics;

C   Maximum flue gas flow rate (or velocity) and maximum waste feed rate, to assure sufficient residence time for destruction of organics and to prevent incomplete combustion due to waste overcharging;

C   Carbon monoxide concentration in exhaust gas, as an ongoing indicator of combustion efficiency;

C   Other operating requirements as necessary to ensure that performance standards are met.

Control parameters are important because performance measures, such as DRE, cannot be directly and continuously monitored after the trial burn. The control parameters provide a means for continuously assuring that operations remain within the range demonstrated during the trial burn. Guidance pertaining to these parameters has been provided previously (EPA 1983 and 1989) and is not repeated here. EPA's 1989 guidance also addresses the importance of establishing operating parameters for air pollution control devices (APCDs), including wet and dry scrubbers, fabric filters, and electrostatic precipitators (ESPs). APCD parameters include minimum and maximum pressure drops, temperatures, flow rates, pH, and power.

Standards for BIFs, including boilers, cement kilns and lightweight aggregate kilns that use hazardous waste as a fuel source, are found in 40 CFR Part 266, Subpart H. These standards were published on February 21, 1991. 40 CFR Part 266, Subpart H requires that BIFs comply with a DRE performance standard as well as emission standards for metals, HCl, Cl_2, particulate matter, carbon monoxide, and total

hydrocarbons. The February 21, 1991 rule also subjected BIFs to the general permitting provisions applicable to incinerators, including the requirement to submit a RCRA Part B permit application.

The BIF standards for 10 metals (antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium), as well as for HCl and Cl_2, were developed to limit risks from the inhalation exposure pathway. Standards for the carcinogenic metals arsenic, beryllium, cadmium, and hexavalent chromium are based on an aggregate (all carcinogenic metals) maximum potential excess lifetime carcinogenic risk for an individual of no greater than 1 in 100,000 (1E-5) from the direct inhalation exposure pathway. BIF standards for metals causing health effects other than cancer are based on oral reference doses (RfDs) converted to reference air concentrations (RACs) or published reference concentrations (RfCs) in air. Standards for lead are based on 10 percent of the National Ambient Air Quality Standard (NAAQS). HCl and Cl_2 emission rate limits are based on RfCs and RACs. RACs are also available for nickel and selenium, and these metals have sometimes been limited in addition to the BIF metals as necessary to protect human health and the environment (EPA 1992a).

Organic emissions from BIFs are controlled using a DRE standard (the same standard as for incinerators) and by limiting carbon monoxide (and in some cases total hydrocarbon) concentrations in stack gas (40 CFR Part 266 Subpart H; EPA 1992b). The BIF rule also recognizes that hazardous waste combustors equipped with dry APCDs operating between 450 and 750 EF may emit higher concentrations of D/Fs than units equipped with other types of APCDs. 40 CFR Part 266 Subpart H requires risk evaluations for BIFs equipped with dry APCDs operating at 450 to 750 EF to demonstrate that total cancer risk (including D/Fs) is less than 1E-5 for the inhalation exposure pathway.

The regulation of metals under the BIF rule led to the need for an additional performance test condition at some facilities, conducted at a high combustion temperature, in order to maximize metal volatility. Thus, under the BIF rule, the combustor operating envelope may be defined by a low-temperature test to demonstrate DRE and a high-temperature test to demonstrate system removal efficiency (SRE) for metals. Operating limits to control metals that are generally established based on the SRE test condition include maximum combustion temperature, maximum metals feed rates, and appropriate APCD operating parameters (e.g., temperature, pressure drop, flow rate, or power). The BIF rule requires that maximum

metal and chlorine feed rates be established using one of the following approaches: Tier I (assuming zero SRE without site-specific air dispersion modeling), Adjusted Tier I (assuming zero SRE with site-specific air dispersion modeling), Tier II (based on emissions data without site-specific air dispersion modeling), or Tier III (based on emissions data with site-specific air dispersion modeling).   Owners and operators of BIFs may choose to spike the wastes used during the SRE test with metals and chlorine to demonstrate performance at maximum feed rates. Spiking helps to ensure that sufficiently flexible metal and chlorine feed rate limits are established. Similar provisions have been applied at hazardous waste incinerators as necessary to protect human health and the environment.

EPA trial burn and technical guidance documents for incinerators and BIFs (EPA 1983, 1989 and 1992b) describe control parameters typically monitored during trial burn testing. The 1989 document categorizes these control parameters (monitored during DRE or SRE conditions) as Group A, B, or C. Short-term limits, such as hourly rolling averages (HRAs) and instantaneous limits, are typically established for these parameters in the facility's RCRA permit. The Group A, B, and C designations are reviewed below.

Group A control parameters are generally continuously monitored while hazardous waste is being fed to the unit and are generally linked with automatic waste feed cutoff (AWFCO) limits to ensure that waste feed is automatically cut off when specified limits are exceeded. Examples of Group A parameters include maximum and minimum PCC and SCC temperatures, maximum combustion gas velocity, maximum waste feed rate, maximum carbon monoxide concentration, maximum combustion chamber pressure, minimum venturi scrubber differential pressure, minimum scrubber liquid-to-gas ratio and pH, minimum fabric filter differential pressure, minimum wet/dry ESP power input, and minimum wet electrostatic precipitator (WESP) liquid flow rate.

Group B control parameters generally do not involve continuous monitoring and may not be interlocked with the AWFCO system. However, detailed operating records are generally maintained to demonstrate compliance with permitted operating conditions. Examples of Group B parameters include maximum batch size for containerized waste and minimum scrubber blow-down. Some Group B operating parameters, including metal and chlorine feed rates, may be continuously monitored once the supporting analytical data have been entered into a data system.

Group C control parameters are generally set independently of trial burn conditions, and limits are typically based on manufacturers' recommendations and good operating practices. Examples of Group C parameters include maximum burner turndown and minimum scrubber nozzle pressure. Most Group C parameters do not involve continuous monitoring and interlocks with the AWFCO system; however, some may (for example, minimum atomization fluid pressure to a liquid injection burner). Similar to Group B parameters, detailed operating records for Group C parameters are generally maintained to demonstrate compliance with permitted operating conditions.

1.3.2 Site-Specific Risk Assessments

The RCRA performance standards described in Section 1.3.1 were promulgated in 1981 for incinerators and in 1991 for BIFs. Since that time, information has become available to suggest that the RCRA performance standards may not fully address potentially significant risks (EPA 1998a).

As documented in the Mercury Study Report to Congress (EPA 1997a), in technical background documents associated with the hazardous waste combustor MACT standards (RTI 1999), and in EPA OSW human health and ecological risk assessment guidance (EPA 1998a and 1999b), there can be potentially significant risks from the indirect exposure pathways (e.g., pathways other than direct inhalation), especially for bioaccumulative compounds such as D/Fs and mercury. Notable D/F and mercury emissions have been observed from hazardous waste combustion facilities (EPA 1996a and 1997b). The food chain pathway appears to be particularly important, and potential risks associated with indirect exposures often exceed potential risks from the direct inhalation pathway (EPA 1998a). Risks via the indirect exposure pathways were not directly taken into account when the RCRA regulations described in the previous section were developed (EPA 1998a).

Because the RCRA performance standards for hazardous waste combustors do not directly address indirect exposures, EPA recommended in 1993 and 1994 that site-specific risk assessments, including both direct and indirect exposure pathways, be conducted for each hazardous waste combustor seeking a RCRA permit (EPA 1993 and 1994b). Permitting authorities could then use the results of the site-specific risk assessments to determine, on a case-by-case basis, whether operation of the combustor in accordance with

the RCRA standards would be protective of human health and the environment (EPA 1998a). In those cases where a RCRA permitting authority identified a potentially significant risk, it could invoke Section 3005(c)(3) of RCRA (which is commonly referred to as the "omnibus authority" or "omnibus provision") to augment the RCRA permit with additional conditions as necessary to protect human health and the environment (EPA 1998a). As discussed in Section 1.3.3, EPA has recently revised its original recommendation in light of the new hazardous waste combustor MACT standards (EPA 1999c).

Section 3005(c)(3) of RCRA, codified in 40 CFR Section 270.32(b)(2), provides EPA with both the authority and responsibility to include additional terms and conditions in each RCRA facility permit as necessary to protect human health and the environment (EPA 1998a). Under 40 CFR Section 270.10(k), EPA may require a permit applicant to submit the information necessary to establish protective permit conditions under the omnibus authority (40 CFR Section 270.10(k); EPA 1998a). For hazardous waste combustors, the information required to establish permit conditions could include a site-specific risk assessment or the supporting information to conduct a site-specific risk assessment (EPA 1999c). Any decision to add permit conditions based on a site-specific risk assessment must be documented in the administrative record for each facility, and the implementing agency must explain the basis for the additional conditions (40 CFR Sections 124.7 through 124.9; EPA 1998a).

1.3.3 Hazardous Waste Combustor MACT Standards

Final MACT standards for certain hazardous waste combustion facilities were promulgated on September 30, 1999, and establish technology-based limits for D/Fs, mercury, semivolatile and low-volatile metals, HCl and Cl_2, hydrocarbons or carbon monoxide, particulate matter, and DRE (EPA 1999c). These standards were promulgated under joint authority of RCRA and the Clean Air Act. The MACT standards apply to several categories of hazardous waste combustion facilities including incinerators, hazardous waste burning cement kilns, and hazardous waste burning lightweight aggregate kilns. The MACT rule requires that these sources achieve compliance with the standards within three years of the rule effective date and begin performance testing for stack emissions within three years and six months of the rule effective date in accordance with 40 CFR §§63.1206(a) and 63.7(a)(2). MACT emission standards for hazardous waste burning boilers and additional industrial furnaces are anticipated in a future rulemaking.

The MACT standards are viewed as more stringent than RCRA Subpart O and Subpart H standards for incinerators and BIFs (EPA 1999c). A national risk assessment was performed to determine if the MACT standards satisfy the RCRA mandate to protect human health and the environment (RTI 1999). The national assessment was a multi-media, multi-pathway analysis addressing both human health and ecological risk. The assessment was predicated on the assumption that sources whose emissions were above the MACT standards would reduce their emissions to MACT levels, and that sources whose emissions were below the standards would maintain emissions at the existing levels. Based on this national assessment, EPA determined that sources complying with the MACT standards are *generally* not anticipated to pose an unacceptable risk to human health and the environment. However, a definitive finding could not be made (RTI 1999; EPA 1999c). Uncertainties remain, especially related to non-dioxin PICs (which were not evaluated in the national risk assessment), mercury (where bioaccumulation is very dependent on local conditions), and other site-specific factors that could vary from those evaluated in the national assessment. Given these uncertainties, EPA continues to believe that site-specific risk assessments may be warranted in some cases (EPA 1999c).

EPA recommends that permit writers evaluate the need for site-specific risk assessments on a case-by-case basis (EPA 1999c). The recommendation that the need for a site-specific risk assessment be evaluated on a case-by-case basis represents a modification to the site-specific risk assessment policy recommendation that EPA made prior to the publication of the MACT standards in 1993 and 1994, when EPA recommended that site-specific risk assessments be completed as part of the RCRA permitting process for all hazardous waste combustors (EPA 1993 and 1994b). The MACT rule preamble provides a list of qualitative factors to assist in the determination regarding the need for a site-specific risk assessment (EPA 1999c). EPA recommends that the decision be made prior to approval of the MACT comprehensive performance test protocol, to the extent possible (EPA 1999c). Therefore, if risk emissions data have not already been collected during a RCRA trial burn or other test, the necessary data can be collected during MACT performance testing (as appropriate).

In summary, promulgation of the MACT standards does not duplicate, supersede, or otherwise modify the omnibus authority or its applicability to hazardous waste combustors (EPA 1999c). Pursuant to the omnibus authority, the RCRA permitting authority has the responsibility to supplement the MACT

standards as necessary, on a site-specific basis, to ensure adequate protection under RCRA. Site-specific risk assessments provide a quantitative basis for making omnibus determinations at hazardous waste combustors (EPA 1999c). The results of site-specific risk assessments provide numerical information which can be compared to the MACT standards to determine whether risk-based limits are appropriate for a particular source in addition to the MACT requirements (EPA 1999c).

1.4   RISK BURN NOMENCLATURE

Key terms are summarized below. These terms are defined strictly for the purpose of supporting the concepts presented in this guidance and do not supersede regulatory definitions.

Control Parameters   Combustor operations are defined by **control parameters** such as temperature, pressure, flow rates, and feed characteristics. The terms "control parameters" and "feed and operating parameters" are used interchangeably in this guidance.

Emissions Testing   **Emissions testing** refers to the manual collection of stack gas sample(s), followed by chemical analysis to determine pollutant concentrations.

Normal Test   A **normal test** can generally be described as a test where each **control parameter** is maintained either near the historical mean, or between the historical mean and the minimum or maximum (as appropriate) set point, while burning representative, but challenging, feeds. A normal test may be conducted for the purpose of generating emissions data for subsequent evaluation in a site-specific risk assessment and may be used as the basis for establishing permit terms. A normal test includes a minimum of one **test condition**, but may include more.

Operating Envelope   The term **operating envelope** refers to the entire range of operation allowed for a combustor, as bounded by either physical or regulatory constraints.

Performance Test   A **performance test** is a test performed for the purpose of demonstrating compliance with a specific regulatory emission limit or performance standard. Allowable operating limits are established based on the operation demonstrated during the performance test. Thus, the tests are usually conducted under **worst-case** operating conditions. RCRA trial burns and MACT performance tests are both performance tests. For hazardous waste combustors, performance testing may include a low-temperature **test condition** to demonstrate DRE for POHCs and a high-temperature **test**

condition to demonstrate SRE for metals. Additional test conditions may be necessary to resolve potential conflicts between targeted operating parameters.

Risk Burn	A **risk burn** is any **emissions testing** performed for the purpose of collecting emissions data for subsequent evaluation in a site-specific risk assessment. The testing may occur in conjunction with a RCRA trial burn or MACT performance test, or the risk burn may consist of a completely separate test effort. A risk burn includes a minimum of one **test condition**, but may include more.
Run	A **run** is the period of time needed to collect a stack gas sample of sufficient volume for subsequent analysis. During a run, control parameters are typically maintained at the same target set point. A minimum of three runs constitutes a **test condition**.
Test	The term **test** is used generically to refer to any **emissions testing**, without distinction as to the type of test or purpose of the testing.
Test Condition	A **test condition** is comprised of at least three **runs** where **control parameters** are maintained at the same target set point.
Trial Burn	The term **trial burn** refers specifically to **emissions testing** required by RCRA regulations. A trial burn is performed for the purpose of demonstrating compliance with a RCRA regulatory emission limit or performance standard and is used as the basis for establishing allowable operating limits. Trial burns may include a low-temperature **test condition** to demonstrate DRE for POHCs and a high-temperature **test condition** to demonstrate SRE for metals. Additional test conditions may be necessary to resolve potential conflicts between targeted operating parameters.
Worst-Case	The term **worst-case** is used to characterize **emissions testing** where a facility operates near the extreme edges of the **operating envelope**, and where emissions are likely to be maximized. The term "worst-case" is a general, not absolute, characterization. RCRA trial burns and MACT performance tests are generally considered to be worst-case tests.

CHAPTER 2

RISK ASSESSMENT STACK EMISSION DATA NEEDS

The categories of emissions data that are generally necessary for completing a site-specific risk assessment include: (1) D/F emission rates, (2) organic emission rates other than those for D/Fs, (3) metals emission rates, (4) particle-size distribution, and (5) emission rates of HCl and Cl_2. This chapter introduces these data needs and briefly summarizes their significance with respect to protection of human health and the environment.

EPA OSW recognizes that, for many compounds, only limited information is available regarding health effects (EPA 1998a). However, this does not imply that targeted sampling for a limited number of compounds should be conducted for the risk burn (EPA 1998a). Stack emissions should generally be characterized as completely as possible during a risk burn, regardless of availability of toxicological data. Although some compounds may eventually be eliminated from quantitative risk evaluation as suggested by the compound-of-potential-concern (COPC) selection process provided in the EPA OSW risk assessment guidance (EPA 1998a), it is important that all compounds initially be identified and quantified. New toxicological data may become available after the risk burn, or the risk assessor may consider provisional toxicity data or surrogate toxicity data from a similar compound in deciding whether to retain the compound as a COPC (EPA 1998a). Alternatively, a qualitative risk evaluation may be performed for any detected compound and presented as an uncertainty in the risk assessment (EPA 1998a).

2.1   DIOXINS AND FURANS

D/Fs are addressed in Chapter 4 of this guidance. D/Fs can pose significant risks through both direct and indirect exposure pathways. Their propensity to partition to adipose (fat) tissue and to bioaccumulate can

make potential food chain effects particularly significant. According to the dioxin reassessment review (EPA 1995a), the air-to-plant-to-animal exposure pathway is a primary exposure route for humans. Other significant exposure pathways include source-to-surface water-to-fish. Human exposures result from ingestion of contaminated milk, beef, fish, and other foods. D/Fs are believed to promote cancer and other harmful health effects in humans and other receptors, and the potential potency of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin as a carcinogen is currently being re-evaluated by EPA.

D/Fs are a group of anthropogenic chemical compounds created as unintended by-products during combustion and industrial activities (EPA 1995a). As described in Chapter 4, the formation of D/Fs in hazardous waste combustion units is highly dependent on post-combustion temperature, time, and the presence of a reaction surface. In general, D/Fs addressed in this document contain at least four chlorine atoms and can assume a planar configuration that allows for specific biological effects. D/Fs are generally quantified in terms of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalents (TEQ), as discussed in the EPA OSW risk assessment guidance (EPA 1998a). EPA OSW recommends that emissions testing for the tetra- through octa- D/F congeners be performed to support site-specific risk assessments.

Even though the primary focus in this document and in the EPA OSW risk assessment guidance is on the tetra- through octa- D/F congeners, analytical standards have been developed for certain mono- through tri-chloro D/F congeners. EPA encourages stack gas analysis for these mono- through tri-chloro congeners whenever possible. The analysis can be performed at very little increased cost, and the results may support development of a database to determine which (if any) of the mono- through- tri-chloro congeners can act as surrogates for the tetra- through octa congeners (EPA 1999c). Identification of an easily measurable surrogate may support future development of a continuous emissions monitoring system (CEMS) to indicate D/F emissions (see http://www.epa.gov/appcdwww/crb/empact/index.htm).

2.2 ORGANICS OTHER THAN DIOXINS AND FURANS

Organic compounds other than D/Fs are addressed in Chapter 5 of this guidance. Organics can result in increased risks from both direct and indirect exposures. Hazardous waste combustors can emit a variety of trace-level organics. As discussed in Chapter 5 of this document, organic emissions from hazardous waste combustion facilities typically include compounds such as volatile and semivolatile organics, aromatics, polyaromatics, D/Fs, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phthalates, nitrogenated and sulfonated organics, and short-chain alkanes (such as methane and propane). Both PAHs and PCBs are considered to be potential human carcinogens (EPA 2000), and are considered to be toxic, persistent, and bioaccumulative. PAHs are frequently associated with particulate matter emitted from combustion facilities. Combustion units have also been identified as major contributors to overall PCB emissions (Alcock and others 1999; EPA 1997b), and an increasing body of information supports the likelihood that PCBs may be formed in combustion systems regardless of PCB contamination in the feed (Lemieux and others 1999). PCBs may be formed by mechanisms similar to those described in Chapter 4 for D/Fs.

Target analyte lists for specific organics recommended for identification during a risk burn are provided in Appendix B. However, the total identification and quantification of all organics is frequently not possible, which adds to the uncertainty of the risk assessment process. Therefore, Chapter 5 and Appendix B of this document describe a method for Total Organic Emissions (TOE) analysis for quantifying the total mass of organics based on boiling point ranges. This information is useful in indicating the level of uncertainty associated with the risk assessment. To reduce uncertainty, stack gas analyses are also recommended for constituents that are not typically included on target analyte lists, such as tentatively identified compounds (TICs) and simple hydrocarbons.

2.3 METALS

Metals are addressed in Chapter 6 of this guidance. Metal emissions can pose potential human and ecological risks. EPA's BIF rule (40 CFR 266, Subpart H) identifies ten metals which may pose human health risks via the inhalation exposure pathway. These metals are antimony, arsenic, barium, beryllium,

cadmium, chromium, lead, mercury, silver, and thallium. A number of these metals also pose human health risks via the indirect pathways. Mercury, in particular, has significant potential to biotransfer up the food chain through water and sediments to fish and human receptors. Table A-1, "Information on Compounds of Potential Interest," of Appendix A of the EPA OSW human health risk assessment guidance (EPA1998a) and Table A-1, "Chemicals for Consideration as Compounds of Potential Concern," of Appendix A of the EPA OSW ecological assessment guidance (EPA1999b) identify eight additional metals as compounds of potential concern for evaluation of human and ecological risks. These eight additional metals are aluminum, copper, cobalt, manganese, nickel, selenium, vanadium, and zinc.

EPA OSW recommends that a facility conducting a site-specific risk assessment perform stack testing or develop emission estimates based on other information for the eighteen metals listed above. Although some metals may be subsequently eliminated from the risk assessment during the compound of potential concern (COPC) selection process, it is recommended that all eighteen metals be quantified during the test to prevent the need for additional testing later. Potential human cancer risks based on carcinogenic slope factors (CSFs) are typically evaluated for arsenic, beryllium, cadmium, hexavalent chromium, and certain species of nickel. Health effects other than cancer are based on RfDs and/or RfCs for antimony, barium, trivalent chromium, copper, manganese, mercury, certain species of nickel, selenium, silver, thallium, vanadium, and zinc. As explained in Section 2.3.2 of this document, EPA OSW has recommended that potential health effects from lead be modeled using an alternative approach (EPA 1998a).

EPA OSW's ecological risk assessment guidance (EPA 1999b) describes ecological toxicity reference values for a number of ecosystems and receptors including freshwater quality, freshwater sediment, marine and estuarine water quality, marine and estuarine sediment, and specific receptors including earthworms, terrestrial plants, mammals, and birds. Ecological toxicity reference values have been developed for aluminum, antimony, arsenic, barium, beryllium, cadmium, copper, hexavalent chromium, total chromium, lead, mercury, methyl mercury, nickel, selenium, silver, thallium, and zinc. EPA OSW has recommended that these metals be considered during the COPC selection process for ecological risk assessments (EPA 1999b).

EPA OSW's human health and ecological risk assessment guidance (EPA 1998a and 1999b) generally recommend addressing metals in the elemental form, with the exception of mercury, chromium, and nickel.

For mercury, chromium, and nickel, the guidance recommends assumptions regarding valence state or chemical form. Based on the conservative nature of the recommended assumptions, a facility may want to perform speciation sampling during the risk burn or present other information to replace the default assumptions with site-specific data. This is discussed further in Section 6.4 and Appendix B.

2.3.1 Human Health and Ecological Concerns for Specific Metals

The following paragraphs discuss human health and ecological significance of the metals aluminum, cobalt, copper, manganese, nickel, selenium, vanadium, and zinc. This information is provided in the EPA OSW risk assessment guidance, as well as other references, and is summarized here because these metals were not addressed in the original BIF rule (40 CFR 266, Subpart H). All of these metals (except aluminum and cobalt) have published toxicity values (CSFs, RfDs and/or RfCs) in EPA's Integrated Risk Information System (IRIS) (EPA 2000) and/or EPA's Health Effects Assessment Summary Tables (HEAST)(EPA 1997c). IRIS and HEAST do not currently identify toxicity values for aluminum and cobalt. However, an ecological toxicity reference value is available for aluminum, and provisional human health systemic toxicity data are available for cobalt. Since aluminum and cobalt can be readily sampled using the multiple metals sampling train, emissions determinations for both metals are recommended.

Aluminum, zinc, and copper are commonly occurring metals that bioaccumulate through the food chain in their ionic form (Paasivirta 1991). These metals can accumulate in soils and/or aquatic ecosystems. Selenium has been demonstrated to cause significant ecological impacts to wildlife, primarily because of the effects from irrigation return water. Nickel has caused both human health as well as ecological effects, and it is commonly associated with industrial operations such as plating.

Aluminum

Aluminum bioconcentrates in aquatic species and vegetation and can cause toxic effects (Agency for Toxic Substances and Disease Registry [ATSDR] 1999; Paasivirta 1991). In mammals, aluminum is poorly absorbed and is not readily metabolized (Ganrot 1986). From a human health perspective, toxicity values have not been established. Ecological toxicity reference values have been developed for aluminum.

Cobalt

Cobalt is a relatively rare metal that is produced primarily as a by-product during refining of other metals, primarily copper. Industrial exposure to airborne cobalt appears to result in sensitization followed by irritation and pronounced pulmonary effects (Doull and others 1991). Provisional human health systemic toxicity data are available for cobalt. Ecological toxicity reference values have not been developed.

Copper

Copper is an essential trace element required by numerous oxidative enzymes and is found in all mammals and several other classes of organisms; however, high doses can result in adverse effects to humans and ecological receptors (Doull and others 1991). In general, humans are less sensitive to copper toxicity than other mammals (such as sheep and cattle), and healthy adults usually are not affected by exposure to low, chronic doses of copper. Infants and children are susceptible to chronic copper toxicity. Once absorbed, copper is distributed to the liver and can bind to deoxyribonucleic acid or generate free radicals.

Organisms susceptible to absorption of contaminants are most vulnerable to copper toxicity. Aquatic organisms such as algae, fungi, certain invertebrates, and fish represent examples of these types of organisms. Thus, aquatic ecosystems would be the most sensitive to copper loading; however, copper released to surface waters generally precipitates out or adsorbs to sediments (ATSDR 1990). Ecological toxicity reference values have been developed for copper.

Manganese

Manganese is an essential trace element, is present in all living organisms, and is a cofactor in a number of enzymatic reactions. Industrial exposures to large doses of airborne manganese dioxide (or other forms of manganese) can result in manganese pneumonitis, which can result in permanent lung damage. Chronic exposure to airborne manganese can result in central nervous system effects including psychiatric disorders and a Parkinson-like syndrome. Liver cirrhosis has also been observed. It is significant that these effects have only been observed in higher primates such as humans and monkeys and not in experimental animals such as rats (Doull and others 1991). IRIS (EPA 2000) bases the chronic reference dose for inhalation on

data collected during occupational exposures to manganese dioxide; therefore, any potential risks from manganese will be driven by the direct inhalation exposure route. Ecological toxicity reference values for manganese have not been developed.

Nickel

Nickel is a commonly used industrial metal, and it is frequently associated with iron and copper ores. Significant loading of nickel to the atmosphere and surface waters has been observed over the past several decades (Doull and others 1991). EPA has identified certain forms of nickel, including nickel carbonyl, nickel subsulfide and nickel refinery dust, as potential human carcinogens (EPA 1998a and 2000). The BIF rule preamble indicates that nickel carbonyl and nickel subsulfide are not likely to be emitted from combustion devices, given their highly oxidizing conditions. Nickel oxide, which may be emitted from combustion devices, is not identified as a carcinogen by itself. However, the EPA OSW human health risk assessment guidance (EPA 1998a) points out that nickel oxide is a major component of nickel refinery dust, and the components responsible for the carcinogenicity of nickel refinery dust have not been conclusively established. Based on this information, EPA OSW has recommended that inhalation risks from nickel be evaluated using the CSF for nickel refinery dust, or that a facility present information indicating the absence of carcinogenic nickel refinery dust components (EPA 1998a). The approach recommended in the EPA OSW risk assessment guidance of evaluating inhalation risks using the CSF for nickel refinery dust is supported by the risk assessment methodology used in support of the MACT rule (RTI 1999; EPA 1999c) and represents a change in EPA OSW's previous policy (EPA 1992a) where it was recommended that nickel be evaluated as a noncarcinogen. Evaluating inhalation risks using the CSF for nickel refinery dust may result in lower allowable nickel feed rates. For exposure pathways other than inhalation, EPA OSW recommends that nickel be evaluated as a noncarcinogen (EPA 1998a). Additional information on nickel speciation is found in the EPA OSW risk assessment guidance (EPA 1998a) and in Section 6.4.3 of this document. Ecological toxicity reference values have been developed for nickel.

Selenium

Selenium occurs naturally in soils, is associated with copper refining and several industrial processes, and has been used in pesticides. It is an essential element, bioaccumulates in certain species of plants, and has

been associated with toxic effects in livestock (blind staggers syndrome). Soils containing high levels of selenium (seleniferous soils) can lead to high concentrations of selenium in certain plants, which then pose a hazard to livestock and other species. In humans, selenium partitions to the kidneys and liver and is excreted through the urine and feces. Toxic effects in humans include central nervous system and gastrointestinal effects (Doull and others 1991). Aquatic birds are extremely sensitive to selenium; toxic effects include teratogenesis. Ecological toxicity reference values have been developed for selenium.

Vanadium

Vanadium is found in several ores, is associated with petroleum products, and is commonly found in food oils. It is unclear whether or not vanadium has any essential role in human metabolism. Toxic effects of vanadium are usually associated with the inhalation exposure route. Effects of chronic exposure to airborne vanadium compounds in workers include bronchitis, bronchopneumonia, and kidney damage (Doull and others 1991). Animal experiments have confirmed effects on the lungs and kidneys. Ecological toxicity reference values for vanadium have not been developed.

Zinc

Zinc is an essential trace element that is involved with many enzymatic reactions in humans and other species (Doull and others 1991). It generally occurs in the divalent oxidation state. Zinc does bioaccumulate, specifically through the indirect soil-to-vegetable exposure pathway. The most common observed human health effect from zinc would be depression of enzyme production, resulting in copper deficiency. Ecological effects include a tendency to bioaccumulate and toxic effects to vegetation and aquatic organisms (Paasivirta 1991). Ecological toxicity reference values have been developed for zinc.

2.3.2 Risk Characterization for Lead

Information on estimating threshold levels of lead exposure is provided in the EPA OSW human health risk assessment guidance (EPA 1998a). Toxicity factors (CSFs and RfDs) are not available for lead. Therefore, EPA OSW has recommended that adverse health effects for lead be characterized through a direct comparison with media-specific health-based levels, adjusted for background exposure (EPA 1998a).

Under the BIF regulations, emissions and feed rate limits for lead are based on a RAC equivalent to 10 percent of the NAAQS for lead converted to an annual average, or 0.09 micrograms per cubic meter ($\mu g/m^3$). However, this standard only addresses the direct inhalation exposure pathway. Lead can also be deposited to soils, where it can be ingested. Therefore, EPA OSW has recommended that soil lead levels also be evaluated as part of a site-specific risk assessment (EPA 1998a). The fate and transport equations in the EPA OSW risk assessment guidance (EPA 1998a) can be used to estimate soil concentrations from stack emissions.

The neurobiological effects observed in children are used as the sensitive endpoint for evaluating lead toxicity from ingestion. EPA has recommended a maximum lead concentration in blood of 10 micrograms per deciliter ($\mu g/dL$), which is at the low end of the range of concern for adverse health effects in children (EPA 1998a). Potential risks from lead are evaluated based on the application of an uptake/biokinetic (U/BK) modeling approach that evaluates potential risks by predicting blood lead levels associated with exposure to lead. When run with standard recommended default values, the U/BK model can calculate a soil lead concentration in milligrams per kilogram (mg/kg) which corresponds to a prediction that no more than five percent of exposed children will have blood lead concentrations exceeding 10 $\mu g/dL$. In lieu of direct comparison to a target soil level, the EPA OSW risk assessment guidance (EPA 1998a) also describes the approach of running the U/BK model.

2.4   PARTICLE-SIZE DISTRIBUTION

Particle-size distribution is addressed in Section 7.2 of this guidance. Information on particle-size distribution (presented as particle diameters in micrometers, referred to as microns) is needed for the air dispersion and deposition modeling that supports the risk assessments (EPA 1998a). Because particle dispersion and subsequent deposition are directly related to particle size, potential risks are directly dependent on particle-size distribution. In general, most metals and a few organic COPCs with very low volatility are assumed to occur only in the particle phase. Mercury and more volatile organics are assumed to partition between the particle and vapor phases. Very volatile organics are modeled only in the vapor phase.

The EPA OSW risk assessment guidance (EPA 1998a) recommends that facilities perform site-specific

measurements to determine particle-size distribution. Measurements for particle-size distribution will reflect site-specific combustion characteristics and the efficiency of the APCD. Site-specific particle-size measurements are discussed in more detail in Chapter 7 and in Appendix B of this document.

2.5 HYDROGEN CHLORIDE AND CHLORINE

HCl and Cl_2 are addressed in Section 7.1 of this guidance. Potential risks from HCl and Cl_2 are limited to the inhalation pathway. 40 CFR Part 266 Subpart H already requires BIF facilities to sample stack emissions for HCl and Cl_2, and to limit emissions as necessary to meet direct inhalation RACs specified in the regulations. However, updated toxicological information (instead of the RACs specified in Subpart H) may be available and may need to be used for site-specific risk assessments at BIF facilities (EPA 1998a).

For incinerators, 40 CFR Part 264 Subpart O establishes a technology-based emissions limit and requires emissions sampling only for HCl. To support site-specific risk assessments, incinerators may also need to test their stack emissions for Cl_2.

CHAPTER 3

RISK BURNS

In this guidance, the term "risk burn" refers to any testing performed to collect emissions data for subsequent evaluation in a site-specific risk assessment. The testing may occur in conjunction with a RCRA trial burn or a MACT performance test, or the risk burn may consist of a completely separate test effort.

The objectives of a risk burn are to (1) collect appropriate emissions and feed characterization information for evaluation in a site-specific risk assessment, and (2) demonstrate the feed and operating conditions which correspond to measured emission levels. Feed and operating parameters (i.e., control parameters) may be limited and monitored after the risk burn to provide assurance on an ongoing basis that emissions remain at or below the measured levels.

Since EPA may consider the results of a risk assessment and use such information to establish risk-based permit limits under the omnibus authority of RCRA as described in 40 CFR § 270.32(b)(2), the risk burn should generally be integrated with trial burn or performance testing to the extent necessary to produce a consistent set of enforceable permit conditions. Planning is critical, and this chapter highlights key considerations. Terms are defined in Section 1.4.

3.1   RISK-BASED PERMITTING OVERVIEW

When a RCRA permit decision includes a site-specific risk assessment and risk burn, the following activities are generally involved.

PHASE 1: PLANNING

1. **The facility-specific risk burn plan and risk protocol are developed, reviewed, and approved**. EPA OSW recommends that the risk burn plan and site-specific risk protocol be carefully coordinated to assure that the information generated during the risk burn will fully support the risk assessment and

final permit decision.

Collection of appropriate emissions and feed characterization information is a fundamental objective of the risk burn. EPA's recommended data quality objective (DQO) process (EPA 1998c) promotes collection of "the right data the first time." The EPA OSW risk assessment guidance (EPA 1998a) and this document support that objective by identifying and discussing data needs and measurement options. However, project-specific measurement goals should generally be established for each data collection effort. For example, some facilities may decide to achieve lower detection limits for certain constituents to demonstrate that risks are below target levels. Preliminary risk modeling can assist in determining the quantitative targets for the measurement design.

Advance planning is also important in choosing the risk burn operating mode. The risk burn operating mode affects the outcome of the risk assessment, and may also affect the final permit terms. Some hazardous waste combustors operate over a wide range of conditions and emission levels. However, the outcome of the risk assessment is linked to specific emission rates measured while operating under specific operating mode(s). To assure that the combustor continues to operate within the range where emissions have been found to be protective, the RCRA permit may limit control parameters based on the risk burn. Ultimately, the risk burn generally should strike a balance between operating modes which achieve desired permit flexibility, while also achieving protective emissions levels. Early communication between the permit writer and facility is important. A clear understanding of how the permit terms will be derived can assist in determining the risk burn operating modes. Preliminary risk modeling and preliminary emissions testing may also be helpful in planning the risk burn.

PHASE 2: DEMONSTRATION

2. **A risk burn is performed to gather stack emissions data and define the operating envelope that corresponds to the risk assessment.** The recommended control parameters for defining the operating envelope that corresponds to the risk burn and risk assessment are identified in Chapters 4 through 7 of this document. In some cases, these parameters may need to be limited in the permit to ensure (on an ongoing basis) that emissions remain below the levels that were measured during the risk burn and found to be protective. Many of the control parameters identified in Chapters 4 through 7 are identical to control parameters which are limited to ensure compliance with regulatory performance standards. Therefore, few (if any) additional permit limitations based on the risk burn may be necessary when the risk burn can be performed in conjunction with a RCRA trial burn or MACT performance test, and when emissions are already controlled to risk burn levels by regulatory limits on key control parameters. A greater number of permit limitations may be necessary when the risk burn and performance tests reflect different operating modes.

3. **A risk assessment is performed to verify that the demonstrated operation does not present significant risk to human health or the environment.** The site-specific risk assessment may either be performed using the actual data from the risk burn, or using a combination of risk burn data and other information. For example, a regulatory standard or allowable permit limit for metals might be evaluated in combination with actual emissions data for specific organics.

Additional iterations of the risk assessment may be performed if the initial evaluation indicates

potentially unacceptable risks. Subsequent iterations might consider additional site-specific information that is more representative of the exposure setting, or reduced emissions (EPA 1998a). However, in most cases, the need for emissions reductions should generally be identified as part of the risk burn planning process, well in advance of performing the risk assessment.

4. **A permit decision is made, either to issue or deny**.

PHASE 3: VERIFICATION

5. **Conditions in addition to those specifically required by regulation may be included in the RCRA permit as necessary to protect human health and the environment**. The final permit represents an important and integral conclusion to the risk-based permitting process. The risk burn and risk assessment are merely tools; it is the final permit that defines what operational conditions are necessary to protect human health and the environment and how that will be assured on an ongoing basis (i.e., risk-based permit limitations). Depending on site-specific considerations, risk-based permit limitations may be necessary to prevent operation at conditions which could result in higher emissions than those represented by the risk burn and risk assessment.

Risk-based permit terms must be justified on a site-specific basis as limitations that are necessary to protect human health and the environment. EPA OSW recommends that the permitting authority consider a number of factors including, but not limited to, the operating mode(s) demonstrated during the risk burn, the emission levels evaluated in the risk assessment, the conservatism of the risk assessment assumptions, the outcome of the risk assessment, and the extent to which emissions are already controlled by regulatory standards or other limitations. Potential risk-based permit limitations include:

C   *Emissions limits and stack testing.* Specific emission limitations may be cited in the permit for certain pollutants. Since most emissions can only be verified by manual stack measurements, the permit may include a schedule for periodic stack testing to confirm that emissions remain below levels that may present a significant risk to human health and the environment.

C   *Feed restrictions, operating limits and monitoring.* Emission levels generally cannot be verified continuously. However, feed restrictions and operating limits may be established based on the risk burn as surrogate indicators of emissions. The feed and operating control parameters can then be continuously monitored to assure that emissions remain below the measured levels on an ongoing basis.

C   *Other limitations.* Other permit limitations may be established to control potential risks as necessary to protect human health and the environment. For example, environmental sampling may be specified to confirm that ambient concentrations of certain pollutants do not reach levels that may present a significant risk to human health and the environment.

As evident from this risk-based permitting overview, EPA OSW believes that the risk burn, risk assessment, and final permit terms will be closely linked for situations where the RCRA permitting authority has determined that a site-specific risk assessment is necessary. The risk burn plays a key role in the process. Operation during the risk burn may affect whether the measured emissions are found to present potential risk to human health and the environment. In addition, operation during the risk burn can define an operating envelope that establishes the working assumptions for the risk assessment and final permit terms. Within the bounds of the operating envelope demonstrated during the risk burn, emissions are characterized and evaluated for potential risk by the risk assessment. Outside of those bounds (unless additional information is available), emissions and risks may be unknown.

3.2   RISK BURN OBJECTIVES

This section discusses risk burn objectives in more detail. The objectives of the risk burn are to (1) collect appropriate emissions and feed characterization information for evaluation in a site-specific risk assessment, and (2) demonstrate the feed and operating conditions which correspond to emission levels that do not present a significant risk to human health or the environment.

3.2.1   Collection of Appropriate Emissions and Feed Characterization Information

As discussed in Chapters 1 and 2, collection of site-specific risk assessment data at hazardous waste combustion facilities generally involves stack sampling and analysis for D/Fs, non-D/F organics, metals, particle-size distribution, and HCl and Cl_2. Prior to data collection, EPA OSW recommends that specific measurement objectives be developed for the risk burn plan and associated quality assurance project plan (QAPP) to assure collection of complete and useable data.

EPA guidance on quality assurance project plans (EPA1998c and 1998d) describe recommended information to be included in a QAPP. The QAPP identifies a project's technical and quality objectives and documents how quality assurance and quality control will be applied to assure that the data support technically sound decision-making. In addition, the QAPP may identify potential limitations regarding use of the data.

EPA OSW recommends that, whenever possible, project-specific measurement objectives be defined considering information from a preliminary risk assessment . High detection or quantitation limits, presence of common laboratory contaminants, and sampling artifacts can artificially inflate risks. A preliminary risk assessment can provide information regarding the necessary detection or quantitation limits and constituent concentrations for demonstrating that risks are below levels of concern. If a proposed measurement option will not attain the quantitative objectives, the measurement design may need to be modified. For example, if lower detection or quantitation limits are needed, a longer sampling duration or use of a high resolution analytical finish might be considered. Conversely, if a facility can tolerate higher detection or quantitation limits, more economical measurement options might be selected. As an example, a single semivolatile sampling train might be used to sample for D/Fs, PCBs, PAHs and semivolatile organics (when a single train is used for multiple determinations, the train components are split and detection limits for the semivolatile organics increase). Detection and quantitation limits are discussed in more detail in Appendix B.

The recommended detection or quantitation limits that should generally be reported when constituents are not detected in a stack gas emissions sample are discussed in Section 8.1.1 of this document. It is also recommended that a facility inform the laboratory of preferred reporting conventions prior to development of the risk burn QAPP and analysis of the risk burn samples.

EPA OSW recommends that the risk burn plan and QAPP also address complete characterization of the feed materials to be burned during the risk burn, including wastes, fuels, raw materials, and spike materials. Data equivalent to the following should generally be generated for each feed material:

- C Proximate analysis, or a comparable evaluation, to determine physical properties including moisture, percent solids, heating value, ash, and viscosity or physical form, as well as to determine approximate chemical properties including total organic carbon, total chlorine, total organic halogens, and elemental composition;

- C Quantification of total metals feed rates for aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc;

- C Survey analysis or a comparable evaluation to provide an overall description of the chemistry of the sample in terms of the major quantities and types of organic compounds that are

present, as well as identification and quantitation of trace quantities of persistent, bioaccumulative, and toxic constituents based on analysis for volatile organics, semivolatile organics, PCBs, PAHs, and facility-specific compounds.

These data typically define a facility's baseline with respect to long-term impacts and potential effects on human health and the environment. When constituents are not detected in a feed matrix, it is recommended that the Sample Quantitation Limit (SQL) as described in *Guidance for Data Useability in Risk Assessment* (EPA 1992c) be reported, with appropriate consideration of the level of dilution necessary to perform the analysis.

EPA OSW recommends that the implications of different measurement options be fully considered during the initial planning stages of the risk burn. Risk burn measurement issues and data analysis are discussed further in the EPA OSW risk assessment guidance (EPA 1998a), and in Section 8.1 and Appendix B of this document.

3.2.2 Demonstration of Operating Modes

The second objective of a risk burn is to determine the feed and operating conditions which will ensure that emission levels do not present a significant risk to human health and the environment. The operating mode during the risk burn may affect the outcome of the risk assessment and, subsequently, the final permit decision. For this reason, EPA OSW recommends that preliminary information regarding potential emission rates and anticipated permit limitations be obtained early in the risk burn planning process.

Useful information regarding potential emissions and risks can be obtained by performing mini-burns and preliminary risk evaluations. Mini-burns involve stack sampling to collect limited emissions data prior to full scale testing. Emissions can also be estimated based upon data gathered at a similar facility, or by performing conservative engineering calculations. A preliminary risk evaluation indicates the degree of potential risk associated with the emissions levels that are anticipated for the risk burn. If the preliminary risk assessment indicates that anticipated emissions are likely to present a significant risk to human health and the environment, a facility may choose to reduce the emissions of certain compounds prior to

conducting the risk burn. Emissions reductions might involve simple refinements to the risk burn plan, such as lowering a target metals feed rate, or more complex measures, such as physically modifying the unit (subject to approval by the regulatory agency).

The risk burn operating mode may also be influenced by the permit limitations which are anticipated to be established based on the risk burn. Chapters 4 through 7 identify key control parameters associated with emissions of specific contaminants (D/Fs, non-D/F organics, metals and HCl/Cl$_2$) and specific types of hazardous waste combustion facilities (incinerators, boilers, cement kilns, and lightweight aggregate kilns). Depending on site-specific considerations, limitations for these parameters (or other parameters identified by the permit writer) may be established in the permit from the risk burn to provide assurance on an ongoing basis that emissions remain at or below levels which may pose a significant risk to human health and the environment. Communication between the permit writer and facility regarding the types of permit limitations to be established, as well as the manner in which the limits will be established, assists in targeting risk burn operating modes to achieve desired permit flexibility.

3.3   INTEGRATION OF RISK BURNS AND PERFORMANCE TESTING

In this guidance, the term "performance testing" refers to testing performed for the purpose of demonstrating compliance with a regulatory emission limit or performance standard. RCRA trial burns and MACT performance tests are both encompassed by this terminology. For hazardous waste combustors, performance testing usually includes low-temperature test condition(s) to demonstrate DRE for POHCs and may include a high-temperature test condition to demonstrate SRE for metals.

The risk burn may be associated with (1) low-temperature test conditions conducted to demonstrate DRE of POHCs, (2) a high-temperature SRE test condition conducted to establish metal feed rates and to account for metals emissions and partitioning, and/or (3) a separate test condition (which may be conducted at normal operating conditions) specifically for the collection of risk assessment data. Fewer permit limitations based on the risk burn may be necessary when the risk burn can be performed in conjunction with a RCRA trial burn or MACT performance test. A greater number of permit limitations may be necessary when the risk burn and performance tests reflect different operating modes.

Decisions regarding integration of the risk burn and DRE/SRE performance tests are not intuitive. The objectives and parameters for each potential test condition should be carefully evaluated, and the similarities and conflicts identified. Adjustments may be necessary in order to combine test conditions. The remainder of Chapter 3 presents information to guide permit writers and facility personnel through considerations which affect test design. A flow chart (Figure 3-1) provides an overview of the process.

3.3.1 Combined Testing

In deciding whether to perform the risk burn in conjunction with DRE/SRE performance testing, EPA OSW recommends that practical considerations, such as timing, be considered, as well as the following factors:

- C   emissions evaluation;

- C   waste selection and feed parameters;

- C   operating parameters.

3.3.1.1 Emissions Evaluation

Section 3.2.2 discusses EPA OSW's recommendation that a preliminary emissions and risk evaluation be conducted to assess the need for emissions reductions prior to the risk burn. An emissions evaluation also provides information that can be factored into the decision of whether to integrate the risk burn and DRE/SRE performance tests. As discussed in Section 1.3.1, DRE and SRE tests are generally conducted under "worst-case" conditions which tend to maximize emissions. For example, the SRE test may involve spiking to increase metal feed rates above normal levels, resulting in high metal emission rates. However, combustion risk assessments typically assess potential risks associated with operation over 30 or more years (EPA 1998a). Incorporating emissions data from DRE and/or SRE testing into the site-specific risk assessment could be overly conservative, given that a facility will not operate at the edges of its operating envelope or emit at maximum levels for the entire time. Under certain circumstances, it may be appropriate to consider emissions data generated during normal operation of the combustion unit in the risk assessment.

Emissions during normal operations (as compared to emissions during DRE or SRE conditions) may better represent the average emissions and risks posed by the combustion facility over its operating life.

When "worst-case" emissions from the DRE/SRE test conditions are not projected to pose a significant risk to human health and the environment, then a facility may choose to minimize the number of test conditions and resulting permit limitations by combining the risk burn and performance tests. Otherwise, the facility and permit authority might explore the possibility of performing the risk burn (or a portion of the risk burn) under normal operating conditions as a separate test effort. The option of collecting data under normal conditions is discussed further in Section 3.3.2.1.

It is important to keep in mind that different approaches may be chosen for different constituents (D/Fs, non-D/F organics, metals, etc.). In addition, the risk assessment can be performed using information other than actual test data for certain constituents. For example, emission rates for some metals can be calculated from metal feed rates and conservative zero SRE assumptions (i.e., no partitioning or removal). A facility may also choose to evaluate a regulatory emission limit for a particular constituent in the risk assessment instead of actual test data (in this case, testing simply confirms whether and under what conditions the regulatory standard can be met). EPA OSW recommends that the risk burn plan and risk protocol clearly designate which emissions levels for the risk assessment will be based on actual test data, and which emission values will be supplied from another source. These choices are discussed further in Sections 3.5 and 8.2.

3.3.1.2   Waste Selection and Feed Parameters

Waste selection and feed parameters may also influence the decision of whether to perform the risk burn in conjunction with a DRE or SRE performance test. As discussed later in Chapters 4 and 5, EPA OSW recommends that representative wastes generally be burned during collection of risk burn emissions data for D/Fs and non-D/F organics, and that actual wastes, and not surrogate wastes synthesized from pure compounds, be used to the extent possible.

In some cases, the preference for use of actual waste during the risk burn may be incompatible with the waste selection criteria for the DRE or SRE performance test. For example, synthetic "wastes" (wastes

mixed from pure compounds) are sometimes utilized during performance tests to achieve the worst-case conditions targeted for those tests. Synthetic wastes may be chosen for DRE or SRE performance tests because of analytical interferences between the designated POHCS and constituents present in actual wastes, because of incompatibilities between actual wastes and spiking materials, or because actual waste volumes are insufficient for completion of three runs per test condition. If circumstances preclude use of actual wastes (or actual waste spiked with POHCs or other compounds) during the DRE or SRE test conditions, then integration of risk-based data collection with performance testing may not be an appropriate option. Additional information on balancing the use of real wastes versus synthetic wastes is found in Section 5.2.2.

This document also identifies key feed parameters which may affect emissions of D/Fs (Chapter 4), non-D/F organics (Chapter 5), metals (Chapter 6), and HCl/Cl$_2$ (Section 7.1), and which EPA OSW recommends be demonstrated during the risk burn. Feed parameters associated with DRE and SRE testing are identified by regulations, and additional recommendations are discussed in other guidance (EPA 1983, 1989 and 1992b). If there is close overlap and little conflict between the risk burn and DRE/SRE feed targets, then a facility may prefer to integrate the risk burn and performance tests. Otherwise, it might be preferable to perform the risk burn (or a portion of the risk burn) as a separate test effort.

3.3.1.3   Operating Parameters

The operating parameters to be demonstrated during the risk burn may also influence whether the risk burn is performed in conjunction with a DRE or SRE performance test, or as a completely separate test effort. This document identifies key operating parameters which may affect emissions of D/Fs (Chapter 4), non-D/F organics (Chapter 5), metals (Chapter 6), and HCl/Cl$_2$ (Section 7.1), and which EPA OSW recommends be demonstrated during the risk burn. Operating parameters associated with DRE and SRE testing are identified by regulations, and additional recommendations are discussed in other guidance (EPA 1983, 1989 and 1992b). If there is close overlap and little conflict between the risk burn and DRE/SRE operating targets, then a facility may prefer to integrate the risk burn and performance tests. Otherwise, it might be preferable to perform the risk burn (or a portion of the risk burn) as a separate test effort.

3.3.2   **Separate Testing**

Section 3.3.2 identifies circumstances where it may be appropriate to perform the risk burn independently from the DRE/SRE performance tests. In some situations, a facility may prefer to perform all or part of the risk burn under normal operating conditions to better represent the average emission levels expected over the operating life of the unit. Testing at normal conditions is discussed in Sections 3.3.2.1 and 3.3.2.2. Alternatively, separate testing may be appropriate because of logistical conflicts, such as timing, or to resolve a conflict between the risk burn and DRE/SRE waste feed or operating targets. Separate testing to resolve a conflict is discussed in Section 3.3.2.3.

3.3.2.1   **Testing at Normal Conditions**

As explained in Section 3.3.1.1, it may be appropriate in certain circumstances to perform the risk assessment using emissions data generated during normal operation of the combustion unit. If a facility requests that emissions data collected under normal operating conditions be evaluated in the risk assessment, then an additional test condition (separate from the DRE/SRE test conditions) may be suggested in the risk burn plan. This additional condition is optional and is performed by the facility on a voluntary basis.

The permitting authority should generally consider proposals for use of emissions data generated under normal operating conditions in the risk assessment (in conjunction with or instead of data generated during a DRE or SRE test) on a case-by-case basis. Additional permit limitations may be needed to ensure that conditions represented as normal during the test are, in fact, normal over the long-term operation of the facility.

Some facilities may view the prospect of extra permit limitations as a disincentive to performing the risk burn (or a portion of the risk burn) under normal operating conditions. However, the "verification" phase of risk-based permitting has been explained in Section 3.1, and the logic is repeated here for emphasis. The permit endeavors to prevent operation at conditions which could result in higher emissions than those evaluated in the risk assessment and found to pose an insignificant risk to human health and the environment. If emissions data from testing at normal conditions are evaluated in the risk assessment (in

lieu of emissions data from "worst-case" DRE/SRE testing) and it is determined that such emissions do not present a significant risk to human health and the environment, then the permit should generally ensure that those emissions, on average, are not exceeded over the long term. Operating limitations from the DRE/SRE test conditions may not offer this assurance, because they represent operating extremes and elevated emissions. Thus, additional operating limitations may be needed to assure protection of human health and the environment. Although these extra permit limitations may indeed be viewed by some facilities as a disincentive to performing a risk burn under normal operating conditions, the decision to pursue testing at normal conditions rests completely with the facility.

It is important to mention that data from testing under normal conditions and data from testing under "worst-case" DRE/SRE conditions may sometimes be evaluated in a risk assessment as two completely separate risk scenarios (for example, to support a more informative risk communication strategy). Provided that "worst-case" emissions from DRE/SRE test conditions are evaluated in the risk assessment and it is determined that they do not present a significant risk to human health and the environment, then extra permit conditions to assure normal operation should not be necessary. Under these circumstances, the regulatory and permit limitations associated with the DRE/SRE testing would ensure that ongoing emissions remain below levels that may present a significant risk to human health and the environment.

3.3.2.2   Defining and Verifying Normal Conditions

Emissions data collected under normal operating conditions may reflect lower emission rates and lower, but more representative, potential risks. However, it may not be appropriate for every facility to use emissions data collected under normal conditions in the risk assessment. EPA OSW recommends that the following be considered when determining whether to test at normal conditions:

1. ***Can the facility provide sufficient information to define normal feed and operating conditions?***

    To use emissions data generated during testing at normal conditions in the risk assessment (in lieu of data generated during a DRE or SRE test), a facility should be able to characterize "normal" for their operations. This characterization could involve plotting control parameters over time, assessing typical variation, determining means and standard deviations, characterizing feed variability, or a combination of these and other approaches. For the feed characterization, EPA OSW recommends that both the hazardous and non-hazardous inputs (including fossil fuels, raw

materials, and non-hazardous wastes) be considered. For example, mercury in coal can contribute to potential risks and should be considered in the feed characterization.

Successful characterization of "normal" may be more probable when a facility burns wastes that have little temporal variation in chemical and physical properties, at relatively constant rates, and under operating conditions that do not fluctuate widely. Facilities that do not operate within these guidelines, including facilities that burn highly variable wastes, could experience more difficulty defining "normal." If a facility cannot define "normal" for their operation, collection of data for the risk assessment may need to be performed in conjunction with the DRE/SRE conditions.

Site-specific factors will inform what constitutes a "normal" test condition. However, a "normal" test can generally be characterized as a test where each control parameter is maintained either near the historical mean, or between the historical mean and the maximum or minimum set point (as appropriate), while burning representative, but challenging, feeds. The goal for burning representative, but challenging, feeds simply means that wastes which may cause elevated or more highly toxic emissions are preferred for the test. Examples include difficult-to-burn wastes, wastes that contain dioxin/furan precursors, or wastes that contain toxic or bioaccumulative constituents. For example, a hexachlorobenzene waste stream would be preferred over a methanol stream if both are routinely processed.

2.   ***Can the facility identify additional permit limitations and record keeping provisions to ensure that the facility does not operate in excess of the normal conditions over the long term?***

Facilities choosing to use emissions data collected under normal operating conditions in the risk assessment (instead of data collected under "worst-case" DRE/SRE conditions) may be subject to additional permit limitations as necessary to protect human health and the environment. Additional limitations may be necessary to ensure that, on average and over the long term, emissions remain within the boundaries represented by a risk assessment. The permit terms may include long-term (monthly, quarterly, semiannual, and/or annual) average limits for certain control parameters, or use of control charts similar to those used for industrial quality control. For example, the control charts could be used to ensure that long-term variation does not exceed one or two standard deviations from the mean. Waste tracking and record keeping may also be specified. The permit may specify that significant changes be reported to the permitting authority. These changes may be subject to review and determination of the need for possible retesting.

Permitting approaches involving long-term averaging should generally be considered very carefully. In some cases, long-term averaging may not achieve the intended objective of maintaining ongoing emissions at levels that do not present a significant risk to human health and the environment. The main consideration, for a given control parameter, is whether high emissions caused by short-term perturbations outside of a certain operating range can be offset by lower emission rates during periods of more normal operations. A long-term averaging period may be utilized effectively when a control parameter exhibits a linear relationship with emissions. For example, elevated metals emissions from higher metals feed rates can generally be offset by commensurate periods of operation at lower metal feed rates. However, for other parameters, perturbations simply increase overall emissions. For example, when an interruption in caustic feed to a scrubber causes excess acid gas emissions, a facility cannot compensate by subsequently adding more caustic. In this situation, a long-term averaging approach may not be appropriate.

The facility should propose a permitting approach for ensuring that, over the long term, the unit does not operate in excess of the conditions represented as normal during the test. Most likely, the approach will closely mirror the approach used to define "normal" in the first place. It should generally not be necessary for the permit approach to be so conservative that operation during the "normal" test is driven towards the extreme edges of the operating envelope (thereby negating the point of the normal test). On the other hand, if testing near an operating extreme seems necessary to reflect variations in everyday operation, then it may be appropriate to reconsider whether "normal" can truly be defined for that operation.

3. *Are there additional site-specific considerations?*

It may be appropriate to use emissions data collected under DRE and/or SRE conditions in the risk assessment because of other circumstances, such as acute risk concerns. For some constituents, direct inhalation may cause short-term or acute effects. In these situations, EPA OSW has recommended that a maximum, 1-hour emission rate be evaluated in the risk assessment (EPA 1998a). Maximum emission rates are generally achieved under DRE and/or SRE conditions.

One example of a situation where it may be appropriate to use emissions data collected under normal operating conditions in the risk assessment is a BIF facility that wishes to perform testing for metals at normal conditions. If the facility can provide historical data to characterize normal metal feed rates (consistent with the recommendations in Section 3.3.2.2) and if monthly-average metal feed rate permit limits could be established based on the risk burn to assure that ongoing operation remains within the range represented as normal during the test (consistent with the recommendations in Section 3.3.2.2), then it might be appropriate to use emissions data collected under normal operating conditions in the risk assessment. The recommended testing and permitting approach for this situation follows:

C   **SRE Test:** The SRE test is conducted at *maximum metals feed rates*, and could involve metals spiking. Emissions from the SRE test are required to be below allowable BIF emission limits (which are based only on inhalation risks) pursuant to 40 CFR § 266.106. *Hourly rolling average metal feed rate limits* are established in the permit based upon this test.

C   **Normal Test:** This test is conducted at *normal metals feed rates*, without metals spiking. Emissions data from the normal test are evaluated in the risk assessment to determine potential risks from both direct and indirect exposures. *Monthly-average metal feed rate limits* are established in the permit based upon this test.

An example of a situation where it may not be appropriate to use emissions data collected under normal

operating conditions in the risk assessment is a commercial facility with a diverse customer list that randomly burns any hazardous waste available on the test day. This facility may not be able to identify a specific waste that represents normal operations, or may not choose to commit to a waste inventory tracking scheme and long-term averaging to assess whether the test waste remains representative. In this case, it may be more appropriate to collect emissions data for the risk assessment during "worst-case" DRE/SRE performance tests.

In summary, emission rates (and related feed and operating conditions) that are evaluated in the risk assessment should clearly correspond to potential permit terms and conditions. The permit terms can ensure protection of human health and the environment by prohibiting operations outside of the operating boundaries represented by a risk burn and risk assessment that demonstrates emissions will not pose a significant risk. The permit writer should work closely with the facility to determine the appropriate test condition(s) for collection of risk burn data and a corresponding permit approach.

3.3.2.3   Separate Testing to Resolve a Conflict

Even if a facility does not choose to perform risk burn testing at normal conditions, it may be appropriate to perform the risk burn (or a portion of the risk burn) independently from the DRE/SRE performance tests to resolve a conflict. The risk burn may be performed independently because of logistical conflicts (for example, the DRE/SRE testing may have already been completed before the need for risk burn data was identified). The risk burn may also be performed independently to resolve a conflict between the risk burn and DRE/SRE waste feed or operating targets.

Conflicting parameters are key control parameters that cannot be demonstrated simultaneously (e.g., maximum combustion gas velocity and minimum fabric filter pressure differential). A facility may encounter conflicts when attempting to integrate the key control parameters for risk testing (identified in Chapters 4 through 7) with key control parameters associated with DRE/SRE performance testing. To overcome a conflict, it may be appropriate for a facility to perform duplicate tests as follows:

   C   A first set of operating conditions to set limits for all control parameters, excluding the ones in conflict;

C   Additional operating condition(s) to set limits on the conflicting control parameters. To the maximum extent practicable, only the conflicting parameters should be varied from the first set of operating conditions. All non-conflicting parameters should be maintained as constant as possible during all operating conditions.

As discussed in Sections 3.3.1.2 and 3.3.1.3, it is recommended that the risk burn (or a portion of the risk burn) be performed independently of DRE/SRE testing when actual wastes are not utilized for the DRE/SRE test, or when there is a conflict between the risk burn and DRE/SRE feed or operating targets.

3.4   RISK-BASED DATA COLLECTION, EXAMPLE LOGIC

Figure 3-1 provides example logic (based on the recommendations discussed throughout this chapter) for permit writers and facility personnel to consider in determining appropriate test conditions for the risk burn. The first step involves determining whether emissions demonstrated under DRE and SRE conditions are anticipated to present a significant risk to human health and the environment, considering target risk levels as specified by the regulatory agency. EPA OSW recommends that this question be answered by evaluating existing emissions data, by conducting "mini-burns" (as allowed by existing permit or interim status conditions), or by evaluating data from similar facilities in a preliminary risk assessment.

Based on preliminary data analysis, a facility may anticipate that emissions data collected during performance testing (DRE and SRE conditions) will indicate that facility emissions do not pose a significant risk to human health and the environment. This situation is represented on the right-hand side of the flow chart. The permit writer would then work with the facility to determine whether the control parameters identified in Chapters 4 through 7 of this document can be demonstrated concurrently with parameters to be demonstrated during the DRE and SRE tests. If so, then it may be appropriate to perform the risk burn in conjunction with the DRE and SRE test conditions.

FIGURE 3-1

**RECOMMENDED SITE-SPECIFIC RISK ASSESSMENT
DATA COLLECTION FLOW CHART**

Normal Test Conditions   **Performance Test Conditions**
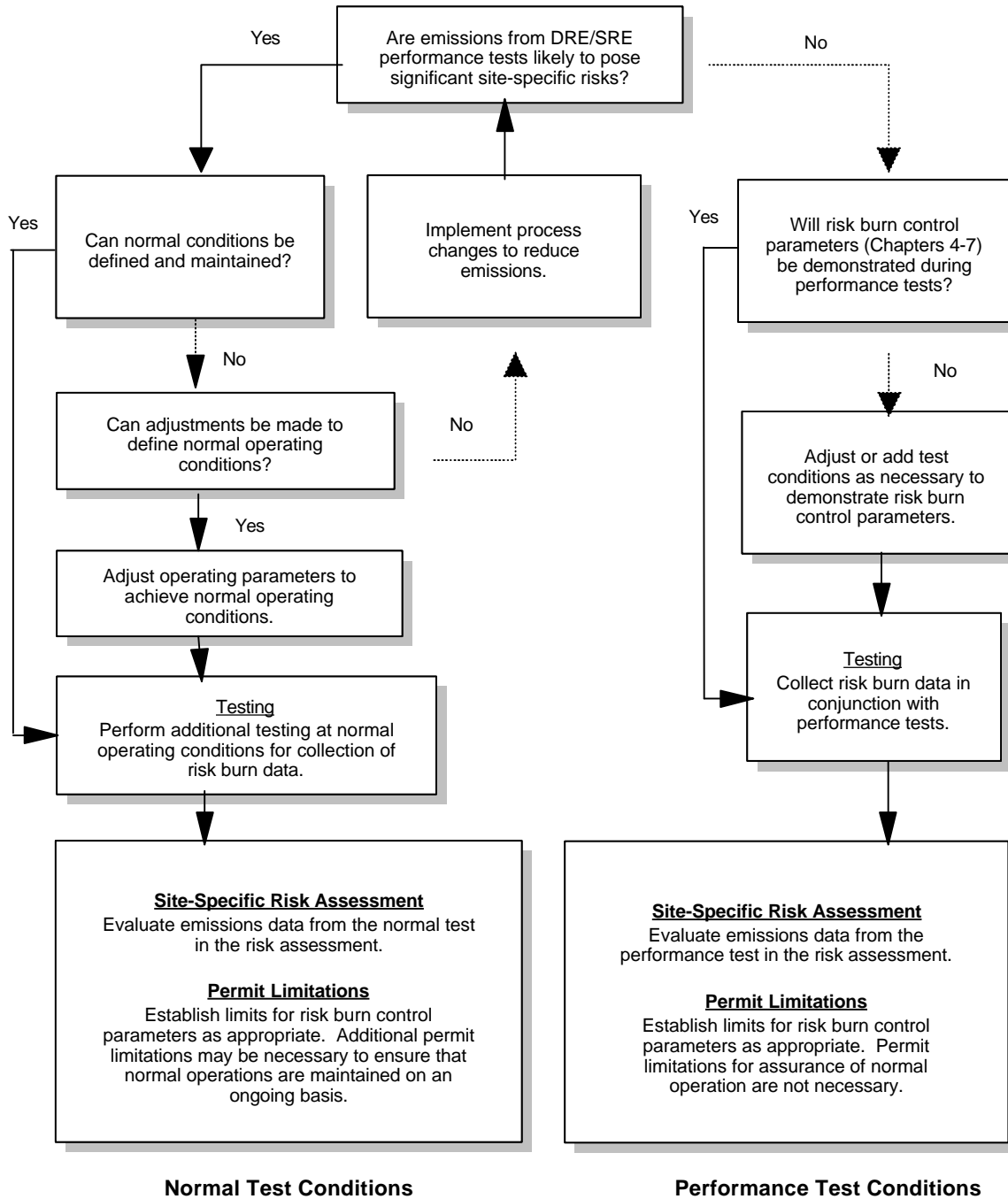
In some cases, the control parameters identified in Chapters 4 through 7 of this document may not be targeted for demonstration during the DRE or SRE test conditions. In these circumstances, it may be appropriate to adjust the DRE/SRE test conditions to demonstrate appropriate control parameters from Chapters 4 through 7, or add extra test conditions as described in Section 3.3.2.3. An example is a hazardous waste boiler that is equipped with a dry APCD for particulate control, but whose waste feeds contain no metals. Since the waste feed does not contain metals at detectable levels, the facility is not required (pursuant to 40 CFR §§ 266.102 and 266.106) to perform a maximum temperature SRE test or to establish maximum inlet temperature limit for the dry APCD to control metals. However, Section 4.2.1.3 recommends maximum inlet temperature to a dry APCD as a primary control parameter related to D/F emissions. If the boiler cannot demonstrate maximum APCD inlet temperature during the DRE test (because of an inability to control APCD temperature independently of combustion temperature, which would be at a minimum), then it is recommended that an extra test condition be added to the test plan specifically to demonstrate maximum APCD temperature while sampling for D/Fs. [Note: The facility could also provide information to justify D/F testing while operating at normal APCD temperature. However, as explained in Section 4.2.1.3, the exponential relationship between D/F emissions and APCD temperature complicates the ability to assure that D/Fs will be maintained at normal levels on an ongoing basis.]

In some situations, the preliminary data analysis might suggest that a facility's worst-case emissions (as measured during performance testing under DRE and SRE conditions) may pose potential risk to human health and the environment if it is assumed that these emissions levels are present all of the time. This situation is represented on the left-hand side of the flow chart. In these circumstances, EPA OSW recommends two options: (1) demonstrate that normal operating conditions can be defined and maintained and perform additional testing at normal conditions; (2) implement process changes to reduce emissions and meet risk-based limits under DRE and SRE conditions. Process changes can include changes to improve combustion efficiency (including burner design and methods of feeding wastes), reductions in feed rates of certain toxic constituents (like metals), or the addition/modification of air pollution control systems.

Facilities that demonstrate the ability to define and maintain normal operating conditions may be subject to additional permit terms as necessary to protect human health and the environment to ensure that the conditions represented as normal during the test are, in fact, normal over the long-term operation of the

facility. These terms can include long-term average permit limitations for waste feed rates, temperatures, and other appropriate control parameters, use of control charts, and/or waste tracking and record keeping. These facilities may also be asked to submit a compliance monitoring plan to demonstrate how compliance with the permit terms will be maintained and documented.

3.5   TEST PLAN SUMMARY INFORMATION

A common understanding regarding how the final permit limits will be developed is integral to the design of the test protocol, and early communication and coordination between the permit writer and facility is essential. The permit writer is responsible for identifying control parameters which may be limited in the permit, and for explaining how specific permit terms may be established based on the test results. The permit writer should generally rely on the facility owner/operator to ensure that risk burn operating conditions are targeted in a manner that supports permit terms that are acceptable to the facility. EPA OSW recommends that the following specific types of information generally be included in the test plan to facilitate this process:

C   For each type of emissions data to be evaluated in the risk assessment (D/Fs, non-D/F organics, metals and HCl/Cl$_2$), an explanation as to whether the facility expects for the risk assessment to be performed using: 1) emissions data from a trial burn or performance test; 2) emissions data from a normal test, or 3) other information, such as a regulatory standard or zero SRE assumptions for metals.

C   For instances where the risk assessment will be performed using emissions data from a normal test, supporting narrative and historical information as necessary to characterize "normal" for the specific operations, as well as a proposed permit approach for assuring that conditions remain within those represented as normal on an ongoing basis.

C   For each test condition, a narrative discussion explaining the overall objectives and approach, as well as a summary matrix listing:

S   The type of test condition (e.g., DRE, SRE, normal, etc.);

S   Emissions data to be collected and regulatory performance standards to be demonstrated;

S   The proposed feed characteristics and operating targets for each relevant control parameter. Control parameters include those listed in Chapters 4 through 7, as well as

the control parameters that will be demonstrated during trial burn or performance testing for DRE, SRE, particulate matter, and HCl and Cl$_2$.

C   A list of conflicting parameters (key control parameters that cannot be maximized or minimized simultaneously), along with a detailed explanation of the reasons for the conflict. The two or more test conditions that will be performed to resolve the conflict should be described, and changes in other control parameters that may be necessary to resolve the conflict should be identified.

C   A complete list of control parameters which are expected to be limited in the permit. This list should be consistent with the proposed test conditions and the following information should be included for each control parameter:

    S   The anticipated permit limit, assuming that all test conditions are executed as planned;

    S   An indication of whether the permit limit will be based on the trial burn or other information (such as a zero SRE assumption for metals);

    S   Specific information on how each permit limit will be established based on trial burn results. This information includes specifying the test condition that will be used to establish the numerical limit and how the numerical limit will be calculated (such as the average over all test runs).

    S   Specific information on how each control parameter will be monitored and recorded to demonstrate compliance with the permit limit (i.e., whether the control parameter will be continuously monitored, the type of record to be maintained and the recording frequency, and what averaging period will be used for the compliance determination).

    S   Statements as to whether the parameter will be interlocked with the AWFCO system, and the corresponding proposed set point.

EPA OSW recommends that the risk burn be integrated with DRE/SRE performance testing as necessary to produce a consistent set of enforceable permit conditions. When permit terms will be established from multiple test conditions, the complete list of anticipated limitations should be reviewed for internal consistency and potential conflicts.

CHAPTER 4

DIOXIN AND FURAN EMISSIONS

D/Fs can pose significant risks through both direct and indirect exposure pathways. This chapter reviews EPA OSW's recommendations for specific operating and feed parameters to be considered for demonstration during collection of D/F emissions data for risk burns. Depending on site-specific considerations, it may be necessary to limit certain of these control parameters in the RCRA permit to protect human health and the environment by ensuring that D/F emissions remain within the levels measured during the risk burn on an ongoing basis.

D/F formation is an extensive and complex subject. This chapter starts with general information and becomes progressively more specific. Background information regarding formation mechanisms is provided in Section 4.1. Key control parameters are reviewed and summarized in Section 4.2, and the relevance of the parameters for each industry category (incinerators, boilers, cement kilns, and lightweight aggregate kilns) is discussed in Sections 4.3 through 4.6. Tables 4-1 and 4-2 summarize the recommendations by industry category.

This guidance relies on available research and emissions databases to draw general conclusions and provide recommendations. However, it is important to note that this guidance cannot encompass every situation. Permit writers should evaluate facility-specific operating trends and information in conjunction with the principles summarized in this document in order to make their facility-specific permit decisions.

4.1   DIOXIN AND FURAN FORMATION MECHANISMS

D/Fs can result from a combination of formation mechanisms, depending on design, combustion conditions, feed characteristics, and type and operation of APCD equipment. D/F formation mechanisms have been studied since the late 1970s when D/Fs were found in municipal waste combustor emissions.

Lustenhouwer originally advanced three theories to explain the presence of D/Fs (Lustenhouwer and others 1980). The theories may now be described as:

1. Survival of trace D/Fs in the fuel.

2. D/F formation from gas-phase precursors which are chemically similar to D/Fs, such as chloro-aromatics, via

    a. homogeneous (gas-gas phase) reactions, or
    b. heterogeneous (gas-solid phase) condensation reactions between gas-phase precursors and a catalytic particle surface.

3. *De novo* synthesis of D/Fs from carbon sources that are chemically quite different from the dioxin and furan ring structures. *De novo* synthesis involves heterogeneous, surface-catalyzed reactions between carbonaceous particulate and an organic or inorganic chlorine donor.

It is now generally accepted that Theory (1) cannot explain the levels of D/F emissions which have been measured from combustors. Most combustion units do not burn D/F contaminated wastes, and Schaub and Tsang have noted that the gas-phase thermal destruction efficiency for D/Fs is high at the flame temperatures typically achieved in a combustion unit (Schaub and Tsang 1983). D/Fs have been found to decompose rapidly at temperatures above 1700 EF (Schaub and Tsang 1983).

Theory (2a) is also believed to play a relatively minor role in the D/F emissions from combustion facilities. An early kinetic model developed by Schaub and Tsang suggested that the homogeneous gas-phase rate of formation could not account for observed yields of D/Fs (Schaub and Tsang 1983). At the high temperatures in a combustion zone, the multi-step process necessary for D/F formation cannot compete with destruction. Although Sidhu and others have subsequently demonstrated pure gas-phase formation of D/Fs (Sidhu and others 1994), the minor role of homogeneous gas-phase formation is evidenced by numerous field measurements which show higher D/Fs downstream of the combustion chamber than in the flue gases immediately exiting the combustion chamber (Gullett and Lemieux 1994).

D/F emissions from combustion devices are now believed to result primarily from heterogeneous, surface-catalyzed reactions in the post-furnace regions of the unit (Theories 2b and 3). Experimental evidence suggests that these reactions occur within a temperature range of approximately 390 to 750 EF (200 to

400 EC) or wider, with maximum formation occurring near 570 EF (300 EC) (Kilgroe and others 1990).

Theories (2b) and (3) are both characterized by heterogeneous, surface-catalyzed reactions. Dickson summarizes the distinctions between the two heterogeneous formation pathways (Dickson and others 1992). Theory (2b) can be distinguished by reactions involving gas-phase chloro-aromatic precursors which might already be present in the fuel, or which could be formed as products of incomplete combustion (Karasek and Dickson 1987; Dickson and Karasek 1987). Theory 3 does not require that chloro-aromatic precursors be present on fly ash or in the gas stream. Instead, both the chloro-aromatic precursors and D/Fs may be synthesized *de novo* from gas-solid and solid-solid reactions between carbon particulates, air, moisture and inorganic chlorides in the presence of a metal catalyst, primarily divalent copper (Stieglitz and others 1989a and 1989b). Activated carbon has also been implicated as a catalyst (Dickson and others 1992).

Dickson has performed studies to quantitatively determine the relative predominance of the two heterogeneous formation pathways (Dickson and others 1992). Yields of polychlorinated dibenzo-*p*-dioxin from the precursor compound pentachlorophenol were 72-99,000 times greater than yields formed from reactions of activated charcoal, air, inorganic chloride and divalent copper catalyst under identical reaction conditions. Citing the kinetic work of Altwicker (Altwicker and others 1990a), Dickson postulated the following:

- C fast reactions involving chloro-aromatic precursors may be expected to predominate in the post-combustion and heat exchanger sections of a combustor, where the temperatures range from 600 to 250 EC and the residence time of the gas stream and entrained particulates is on the order of 1 second, and

- C slower processes such as *de novo* synthesis may influence D/F emissions in dry pollution control equipment, where particulate residence times vary from 1 to about 1000 seconds.

Although both mechanisms may contribute to observed D/F emissions, Gullett and Lemieux have shown that "in flight" formation alone (at residence times less than 5 seconds) is sufficiently rapid to explain the D/F concentrations measured in the field (Gullett and Lemieux 1994).

Molecular chlorine (Cl_2) appears to play a role in D/F formation by chlorinating aromatic D/F precursors through substitution reactions. Chlorination of phenol has been shown to be three orders of magnitude

greater with Cl_2 than with HCl (Gullett and others 1990). Although HCl does not directly participate in precursor chlorination to a significant degree, it can produce molecular chlorine via the Deacon reaction (Griffin 1986; Gullett and others1990):

$$2HCl + \frac{1}{2} O_2 <==> Cl_2 + H_2O, \text{ with copper or other metals serving as catalysts} \qquad \text{(Equation 1)}$$

where:

HCl	=	hydrogen chloride
O_2	=	oxygen
Cl_2	=	chlorine
H_2O	=	water

The Deacon reaction depends on the presence of a metal catalyst to overcome kinetic limitations which would otherwise limit the production of Cl_2 from HCl (Griffin 1986). However, the metal catalyst also serves another important function. Once the aromatic rings have been chlorinated, the metal catalyst supports condensation reactions to form the D/F dual ring structure (Bruce and others 1991; Gullett and others 1992). Gullett has shown that formation of the dual ring structure (biaryl synthesis) is enhanced up to three orders of magnitude in the presence of metal catalysts, such as divalent copper (Gullett and others 1992). Based upon testing with nine different metals and oxidation states, divalent copper appears to demonstrate the strongest catalytic activity (Gullett and others 1992; Stieglitz and others 1989a).

Radical Cl also appears to play a role in D/F formation. Recent work by Gullett shows that radical Cl persists to temperatures where hydrocarbon chlorination occurs (Gullett and others 2000a). This mechanism is a likely chlorination route, and is influenced by combustion conditions and their effect on Cl radical persistence.

Sulfur has been shown to decrease D/F emissions. Substantially lower D/F emissions have been observed from coal-fired power plants than from municipal waste combustors, even though coal-fired utilities operate under conditions that should generally be conducive to D/F formation. The sulfur/chlorine ratio of the fuel may explain the difference. The typical S/Cl ratio in a municipal waste combustor is about 0.2, which is approximately an order of magnitude lower than that found in coal combustion (Raghunathan and

Gullett 1996). Raghunathan and Gullett have demonstrated significant D/F reduction at S/Cl ratios as low as 0.64 in a natural-gas-fired furnace, and as low as 0.8 in a coal-fired furnace (expressed as uncorrected furnace concentrations of parts per million SO_2 /HCl). Additional work has shown that D/F formation is substantially inhibited when the S/Cl ratio is greater than about 1:1 (Gullett and Raghunathan 1997).

Researchers have concluded that sulfur may interfere with D/F formation by (1) SO_2 depletion of Cl_2 (Equation 2), and (2) SO_2 poisoning of copper catalysts (Equation 3) to prevent biaryl synthesis (Griffin 1986; Gullett and others 1992; Bruce 1993; Raghunathan and Gullett 1996):

$$Cl_2 + SO_2 + H_2O <==> 2HCl + SO_3 \qquad \text{(Equation 2)}$$

where:

Cl_2	=	chlorine
SO_2	=	sulfur dioxide
H_2O	=	water
HCl	=	hydrogen chloride
SO_3	=	sulfur trioxide

and:

$$CuO + SO_2 + \tfrac{1}{2} O_2 <==> CuSO4 \qquad \text{(Equation 3)}$$
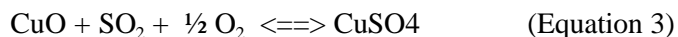
where:

CuO	=	cupric oxide
SO_2	=	sulfur dioxide
H_2O	=	water
$CuSO_4$	=	cupric sulfate

It is also possible that poisoning of the copper catalyst may interfere with the Deacon reaction.

From this background, it is clear that D/F formation involves many complex reactions. A complete understanding of the reaction chemistry may never be possible. However, for units achieving good combustion, the most important reactions appear to depend on gas/solid chemistry in cooler zones

downstream of the combustion chamber. Conditions conducive to downstream formation include (1) presence of particulates, which allow for solid-catalyzed reactions, (2) post-furnace particulate residence time in the critical temperature window (approximately 400 to 750 EF), (3) presence of Cl and organic precursors, including chloro-aromatics, and (4) a shortage of formation inhibitors, such as sulfur. Poor combustion can substantially increase D/F formation, possibly through increased soot formation (providing more catalytic reaction sites for D/F formation), increased formation of PICs (which can serve as D/F precursors), and increased gas-phase formation of D/Fs, although sufficient oxygen also appears to be necessary (Gullett and others, in press). Approaches that have been successfully demonstrated in full scale systems for controlling D/F emissions include:

C   Maintenance of good combustion conditions to limit organic precursors and soot;

C   Rapid flue gas quenching or other measures to minimize post-furnace particulate residence time in the critical temperature zone;

C   Use of formation inhibitors;

C   End-of-pipe flue gas cleaning techniques for D/F removal or catalytic decomposition.

4.2   CONTROL PARAMETERS TO BE CONSIDERED FOR RISK BURNS

As explained in Section 4.1, researchers have concluded that D/F formation mechanisms in combustion systems are extremely complex. D/F emissions cannot be predicted accurately with kinetic models or surrogate monitoring parameters such as carbon monoxide or total hydrocarbons (Santoleri 1995). Even in systems achieving good combustion (with low carbon monoxide concentrations), D/F formation may occur in cooler zones downstream of the combustion chamber (Santoleri 1995). Almost any combination of carbon, hydrogen, oxygen, and chlorine can yield some D/Fs, given the proper time and temperature (Altwicker and others 1990b; Santoleri 1995). Factors such as non-detect levels of chlorine in feed streams, lack of dry APCD systems, presence of D/F inhibitors (such as sulfur), lack of D/F catalysts (such as copper), and lack of D/F precursors (such as chloro-aromatics) may lead to reduced or low emissions of D/Fs. However, because mechanisms of D/F formation are extremely complex and are not well understood, it is not possible to predict with certainty whether a given facility will have significant D/F

emissions.

Since D/F emissions cannot be predicted, it is recommended that D/F emissions testing be performed to develop the emissions data for site-specific risk assessments. This section recommends key control parameters to be considered in establishing D/F test conditions. After the risk burn, these parameters may need to be limited in the permit to protect human health and the environment by ensuring that D/F emissions remain below measured levels on an ongoing basis.

Several of the control parameters identified in this section may already be limited in association with the DRE standard, and a number of the control parameters will be limited pursuant to the requirements of the hazardous waste combustor MACT rule. To the extent that risks from D/Fs are already adequately controlled by regulatory limits on key control parameters, then fewer risk-based limits may be needed in the RCRA permit. However, if regulatory controls are not applicable or sufficiently comprehensive, then additional risk-based limits may be warranted. A greater number of risk-based permit limitations may be necessary when the risk burn and RCRA or MACT performance tests reflect different operating modes.

In formulating the recommendations in Section 4.2, a conservative approach has been taken. It is important that D/F emissions not be underestimated for risk assessments. However, a facility is not precluded from showing, on a site-specific basis, why a less conservative approach may be warranted, or from following the procedures in Section 3.3.2.1 to show that D/F testing should be performed at normal conditions to better represent the risk over the facility's operating life. Conservative recommendations are appropriate for this guidance because the option of testing at normal conditions may not be appropriate for every facility. EPA OSW recommends that conditions conducive to D/F formation first be reviewed to ensure that high-emitting operating modes at a facility are not under-represented by the risk assessment. In addition, the option of testing at normal conditions depends on whether a permit approach can be developed to ensure that emissions remain at or below measured levels. It may be difficult to ensure that "normal" D/F emissions will be maintained on an ongoing basis after the risk burn because of the non-linear relationship between D/F emissions and certain control parameters, such as particulate hold-up temperature (i.e., short-term perturbations outside of a certain operating range can cause high emissions which cannot be offset during periods of more normal operations). Finally, some level of conservatism in the D/F testing and permitting approach may be warranted to compensate for the continuing uncertainty regarding D/F

formation mechanisms in general.

Although Section 4.2 presents each control parameter individually, the relative importance of the parameters with respect to one another should generally also be considered. When one or two control parameters are clearly dominant for a particular system, there may be little benefit to demonstrating and limiting additional parameters. The hierarchical ranking at the end of this section (Section 4.2.6) provides information to be considered in addressing this issue.

Control parameters are categorized according to post-combustion conditions (Section 4.2.1), combustion conditions (Section 4.2.2), feed composition (Section 4.2.3), hysteresis/memory effects (Section 4.2.4), and D/F control technologies (Section 4.2.5). All parameters may not be relevant for all systems, and the information in Section 4.2 should be considered in conjunction with the industry-specific information provided in Sections 4.3 through 4.6, as appropriate, as well as facility-specific information.

4.2.1 Post-Combustion Conditions

The flue gas temperature profile through the D/F formation region (approximately 400 to 750 EF) downstream of the combustion chamber is a critical factor influencing D/F emissions. Even for advanced combustor systems where CO levels are nearly zero (indicating complete combustion), downstream formation of D/Fs may still be significant (Buekens and Huang 1998). Post-combustion situations that should generally be considered during risk burn planning include:

- C   rapid wet quench systems;

- C   partial wet quench temperatures;

- C   dry particulate hold-up temperatures.

4.2.1.1 Rapid Wet Quench Systems

Recommendation -- *EPA OSW recommends that facilities with rapid wet quench systems and "wet"*

APCD systems perform risk burn testing for D/Fs in conjunction with the DRE test conditions, whenever possible. If D/F testing during the DRE test is not feasible (for example, due to timing) consideration may be given to testing at normal conditions, where appropriate (see Section 3.3.2.2).

During the risk burn, demonstration of specific control parameters associated with the rapid quench system should generally not be necessary. Consequently, permit limits for the rapid wet quench system based on the test are not expected to be needed. However, controls based on design specifications may be appropriate in some cases to assure that the quench continues to function properly.

A rapid quench system involves rapid liquid quenching (on the order of milliseconds) from combustion temperatures to saturation temperatures. Facilities with "wet" APCD trains, such as venturi and packed bed scrubbers, utilize rapid wet quench. Wet scrubbers by design operate at stack gas dew point temperatures, which typically range from 170 to 200 EF. Thus, a flue gas exit temperature limit for the quench column or wet scrubbing device is not necessary to ensure that particulates are not held up in the critical 400 to 750 EF temperature window. (Note: This discussion applies to facilities with completely "wet" APCD trains. Temperature limits may be needed for facilities with "dry" APCD components that only perform a partial wet quench prior to a dry APCD, or that initially perform a full quench, but then reheat flue gases downstream of the wet scrubbing system and prior to a dry APCD. Sections 4.2.1.2 and 4.2.1.3 address these situations.)

In systems that perform rapid flue gas cooling from combustion temperatures to saturation (below 200 EF), surface-catalyzed D/F formation reactions are effectively precluded. Hazardous waste combustion facilities utilizing wet APCD systems are among the lowest-emitting sources of D/Fs (EPA 1999d; Santoleri 1998). A database containing more than 40 test conditions indicates that D/F emissions from these facilities are almost always less than 0.4 nanograms (ng) TEQ per dry standard cubic meter (dscm), and are often less than 0.1 ng TEQ/dscm (EPA 1999d). Ullrich describes reductions in D/F emissions which can be achieved through the use of a rapid liquid quench (Ullrich and others 1996).

A notable exception to the low D/F emissions trend for rapid wet quench systems is documented for one source (Source ID No. 330) where two test conditions showed average D/F emissions of 33 and 39 ng

TEQ/dscm, and an individual test run reached a maximum of 76 ng TEQ/dscm (EPA 1999d; Santoleri 1998). This source was burning waste oils with high levels of PCBs (30%). Although other PCB-burning sources have demonstrated low D/F emissions (EPA 1999d), it is possible that the PCBs or PCB combustion breakdown products could be responsible for significant gas-phase precursor formation of D/Fs at Source ID No.330.

The anomalous nature of the high D/F emissions at Source ID No. 330 emphasizes the inherent uncertainty in attempting to predict D/F emissions trends in lieu of actual emissions testing. Even in rapid wet quench systems where post-furnace D/F formation reactions are effectively precluded, the possibility of high D/F emissions cannot be ruled out. Incomplete combustion due to mixing inhomogeneities or cold pockets may generate D/F precursors, and D/Fs may be formed via gas-phase precursor formation mechanisms in regions of the combustion chamber where temperatures are below flame temperatures. These concerns lead to the recommendation for performing D/F testing at DRE test conditions (which usually represent challenging combustion conditions) for rapid wet quench systems whenever possible. Further information regarding the relationship between combustion conditions and D/F emissions is provided in Section 4.2.2.

4.2.1.2   Partial Wet Quench Temperatures

Recommendation -- EPA OSW recommends that facilities that partially quench flue gases to between 570 and 800 °F prior to a dry air pollution control device perform risk burn testing for D/Fs at a maximum post-partial quench flue gas temperature (i.e., at the highest temperature within the 570 to 800 °F range that the facility wishes to achieve during post-risk burn operation). For some facilities, this condition may occur in conjunction with the high temperature SRE test. Unless historical operating data are provided to indicate little variation in post-partial quench temperature, EPA OSW recommends against performing D/F testing at normal or average hold-up temperatures. A permit limit on maximum post-partial quench temperature based on the risk burn may be necessary to protect human health and the environment by assuring that the measured D/F emissions are maintained on an ongoing basis.

Facilities with "dry" APCD components, such as fabric filters and ESPs, often utilize a wet quench for flue gas cooling prior to the APCD. However, unlike the rapid wet quench situation where flue gases are

quenched to saturation, the flue gas upstream of a dry APCD is only partially quenched, and APCD inlet temperatures are maintained well above the dew point.

As explained in Section 4.2.1.1, facilities that rapidly quench flue gases to below saturation temperatures generally have low D/F emissions. However, this may not necessarily be the case for facilities that perform only a partial quench. Waterland and Ghorishi observed significant increases in D/F levels in the flue gas (more than 2 orders of magnitude) as post-partial-quench temperatures increased from 711 to 795 EF (Waterland and Ghorishi 1997). The observed residence time was approximately 0.5 seconds. This phenomenon, termed rapid high-temperature D/F formation, appears to be active in a post-partial-quench temperature range of 570 to 800 EF (Waterland and Ghorishi 1997).

Based on this information, it appears that post-quench temperatures from partial quench systems can be important. Therefore, risk burn testing for D/Fs should generally be performed during a maximum post-partial quench flue gas temperature condition. For some facilities, this condition may occur in conjunction with the maximum temperature SRE test. A permit limit on post-partial quench temperature based on the risk burn may be necessary to protect human health and the environment by assuring that measured D/F emissions are maintained on an ongoing basis.

Unless historical operating data are provided to indicate little variation in post-partial quench temperature, EPA OSW recommends against performing D/F testing at normal or average hold-up temperatures. The exponential relationship observed between the quench temperature and D/F emissions makes it difficult to ensure that "normal" D/F emissions will be maintained on a ongoing basis after the risk burn (i.e., the D/F emissions from one minute of operation at 100 EF above normal cannot be offset by one minute of operation at 100 EF below normal). It is important that D/F emissions not be underestimated for risk assessments. However, a facility is not precluded from showing, on a site-specific basis, why a less conservative approach may be warranted, or from following the procedures in Section 3.3.2.2 to show why D/F testing should be performed at "normal" quench temperatures. If testing at normal temperatures is proposed, the facility should be prepared to explain how a monitoring scheme can be developed to reliably ensure that D/Fs will be maintained at "normal" levels on an ongoing basis.

4.2.1.3 Dry Particulate Hold-Up Temperatures

Recommendation -- EPA OSW recommends that facilities with "dry" particulate hold-up areas between 400 and 750 EF downstream of the combustion chamber perform risk burn testing for D/Fs at a maximum particulate hold-up temperature (i.e., at the highest temperature within the 400 to 750 EF range that the facility wishes to achieve during post-risk burn operation). For some facilities, this condition may occur in conjunction with the maximum temperature SRE test. Unless historical operating data are provided to indicate little variation in the inlet (or outlet, as appropriate) temperature to a particulate hold-up device, EPA OSW recommends against performing D/F testing at normal or average hold-up temperatures.

The locations where temperatures should generally be maximized include: 1) the inlet to dry APCD equipment; 2) the outlet of heat exchangers; and 3) the inlet to extensive runs of un-insulated ductwork at lightweight aggregate kilns where substantial convective cooling occurs. Permit limits on maximum temperatures at these locations based on the risk burn may be necessary to protect human health and the environment by ensuring that D/F emissions are maintained at or below the measured levels on an ongoing basis.

Unless a facility utilizes a completely "wet" APCD system and performs rapid liquid quenching (on the order of milliseconds) to saturation, as discussed in Section 4.2.1.1, there may be one or more "dry" system components downstream of the combustion chamber which are conducive to surface-catalyzed D/F formation via precursor condensation and *de novo* synthesis mechanisms. Downstream components conducive to D/F formation include any devices which preclude rapid quench to below 400 EF, as well as devices where particulates are physically held up in the critical temperature window (approximately 400 to 750 EF). Specific devices include heat exchangers, extensive runs of un-insulated ductwork at lightweight aggregate kilns where substantial convective cooling occurs, and dry APCDs (such as ESPs, fabric filters, and possibly high efficiency particulate air [HEPA] filters).

Data described in numerous literature sources highlight the importance of inlet temperatures for dry APCDs, such as ESPs and fabric filters (Harris and others 1994; Lanier and others 1996; Kilgroe 1996; EPA 1999d and 1999e). In general, these data indicate that, within the D/F formation window of

approximately 400 to 750 EF, D/F formation can increase exponentially with increases in APCD inlet temperature. Thus, dry APCD inlet temperature is a critical control parameter.

Heat exchangers also provide the conditions necessary for surface-catalyzed D/F formation. When flue gas cooling involves a heat exchanger (a waste heat boiler is a type of heat exchanger), the gas is cooled slowly through the catalytic D/F formation temperature region. In addition, particulates may be held up on the heat exchanger tubes. Outlet temperatures from waste heat boilers typically range from 400 to 600 EF (EPA 1999d). Santoleri, citing numerous studies in Germany and the United States, notes that facilities with heat recovery boilers have been found to have higher emissions of D/Fs than facilities without heat recovery (Santoleri 1995). The D/F emissions trend for waste heat recovery boilers is further supported by data collected in support of the hazardous waste combustor MACT rule which indicates that incinerators equipped with recovery boilers have significantly higher D/F emissions than other incinerators (EPA 1997d and 1999d). Acharya has hypothesized that D/Fs in a boiler may be minimized by only cooling combustion gases to about 800 EF (Acharya and others 1991). Although energy recovery might be reduced, the gas temperatures would be maintained outside of the 400 to 750 EF range. Based on this information, the outlet temperature of a heat exchanger is a critical control parameter.

Data collected in support of the hazardous waste combustor MACT rule also document elevated D/F emission rates at some lightweight aggregate kilns, where formation apparently occurred in extensive runs of un-insulated ductwork connecting the kilns to the fabric filters (EPA 1997d and 1999d). Convective cooling in un-insulated ductwork can result in slow gas cooling through the catalytic D/F formation temperature region, and the ductwork provides surface area for particulate hold-up. EPA noted that reductions of D/F emission rates could likely be achieved simply by rapidly quenching gases at the exit of the kiln to less than 400 EF and insulating the ductwork to maintain gas temperatures above the dew point prior to the fabric filter. This information indicates that the temperature at the inlet to extensive runs of un-insulated ductwork at lightweight aggregate kilns (where flue gas can cool through the 400 to 750 EF temperature range) is a critical control parameter.

In summary, the relatively low temperature (approximately 400 to 750 EF) "dry" areas of particulate hold-up downstream of the combustion zone should generally be emphasized for D/F testing. These areas are conducive to surface-catalyzed D/F formation via precursor condensation and *de novo* synthesis

mechanisms. Available data indicate that particulate matter provides the substrate to act as a chemical reactor, given the appropriate temperature, time, and presence of Cl. Thus, any particulate hold-up area (including fabric filters, ESPs, HEPA filters, heat exchangers, and extensive runs of ductwork at aggregate kilns) operating in the critical temperature range can promote D/F formation.

Particulate hold-up temperatures should be considered very carefully in determining the appropriate test condition for D/F testing. In most instances, it is recommended that facilities perform risk burn testing for D/Fs at a maximum particulate hold-up temperature (i.e., at the highest temperature within the 400 to 750 EF range that the facility wishes to achieve during post-risk burn operation). For some facilities, this condition may occur in conjunction with the high temperature SRE test. The locations where temperatures should generally be maximized include: 1) the inlet to dry APCD equipment; 2) the outlet of a heat exchanger; and 3) the inlet to an extensive run of un-insulated ductwork at lightweight aggregate kilns where substantial convective cooling occurs. Permit limits on maximum temperatures at these locations based on the risk burn may be necessary to protect human health and the environment by ensuring that D/F emissions are maintained at or below the measured levels on an ongoing basis. (Note: If the device is maintained *above* the critical temperature range to prevent D/F formation, for example, above 800 EF, a minimum temperature limit may be appropriate instead.)

Unless historical operating data are provided to indicate little variation in the inlet (or outlet, as appropriate) temperature to a particulate hold-up device, EPA OSW recommends against performing D/F testing at normal or average hold-up temperatures. D/F formation has been observed to increase exponentially with increases in temperature over the range of approximately 400 to 750 EF (Harris and others 1994; Lanier and others 1996; Kilgroe 1996; EPA 1999e). This non-linear relationship makes it difficult to ensure that "normal" D/F emissions will be maintained on a ongoing basis after the risk burn (i.e., the D/F emissions from one minute of operation at 100 EF above normal cannot be offset by one minute of operation at 100 EF below normal). It is important that D/F emissions not be underestimated for risk assessments. However, a facility is not precluded from showing, on a site-specific basis, why a less conservative approach may be warranted, or from following the procedures in Section 3.3.2.2 to show why D/F testing should be performed at "normal" temperatures. If testing at normal temperatures is proposed, the facility should be prepared to explain how a monitoring scheme can be developed to reliably ensure that D/Fs will be maintained at "normal" levels on an ongoing basis.

A final consideration involves the use of a reheater in a flue gas cleaning train. One source utilizing a rapid wet quench and wet scrubbing system (EPA 1999d, Source ID No. 602) has reported somewhat higher D/F emissions than those observed from most rapid wet quench systems. This source uses a coil-tube reheater downstream of the wet scrubbing system to reheat flue gases to above saturation temperatures prior to HEPA filtration. The gases are reheated to approximately 250 EF. Although this flue gas temperature is outside of the 400-750 EF range, the reheater tubes provide surface area for particulate hold-up and are estimated to be about 500 EF (EPA 1999d). These tube surface temperatures may promote surface-catalyzed D/F formation. During a risk burn, specific temperature targets for a reheater should generally not be necessary (operation of a reheater is expected to be fairly constant). However, it is recommended that the permit writer ensure that emissions sampling for D/Fs occurs downstream (rather than upstream) of the reheater.

4.2.2 Combustion Conditions

Although D/Fs are primarily formed in the post-combustion zone of combustion systems, the reactants or precursors for D/F formation originate in the combustion chamber itself (Buekens and Huang 1998). This section provides general information regarding the affect of combustion conditions on D/F emissions. Since the general discussion may not be entirely relevant for all systems, the industry-specific discussions provided in Sections 4.3 through 4.6 should also be consulted. In addition, some information may not be relevant to units that operate in a sub-stoichiometric mode. The discussions and recommendations in this section are based on the underlying assumption that all hazardous waste combustors are required by regulation to operate under combustion conditions that meet or exceed 99.99 percent DRE.

4.2.2.1 Target Test Conditions

> *Recommendation -- The complex, multi-variate nature of combustion parameters and their influence on D/F emissions makes it difficult to isolate effects, and thus to conclusively ascertain the relationship between individual parameters and D/F emissions. The difficulty in isolating effects complicates the task of targeting test conditions to ensure that D/F emissions are not under-represented in the risk assessment. To capture the potential range of D/F emissions, it is recommended that facilities perform testing for D/Fs during <u>all</u> planned test conditions (including*

both DRE and SRE conditions) whenever possible.

EPA OSW recommends that the challenging combustion scenarios discussed later in Section 4.2.2.3 be represented during D/F testing (if applicable to a particular system). The challenging combustion situations described in Section 4.2.2.3 include: 1) transient conditions; 2) operation with containerized or batch waste feeds; and 3) high carbon monoxide situations.

The combustion parameters identified later in Section 4.2.2.2 should automatically be addressed when D/F testing is performed during all planned test conditions, since these parameters are typically demonstrated and limited as part of the DRE determination. The combustion parameters listed in Section 4.2.2.2 include: 1) minimum primary and secondary combustion chamber exit temperatures; 2) maximum combustion gas velocity; 3) maximum waste feed rate at each feed location; 4) limitations on waste feed composition and batch feeds; and 5) maximum flue gas carbon monoxide and/or total hydrocarbon concentrations.

The general recommendation for D/F testing during all test conditions may be less appropriate for situations where downstream formation is of little or no concern (i.e., the rapid wet quench/wet APCD configurations discussed in Section 4.2.1.1). When there is minimal potential for downstream formation, D/F emissions will either be low, or are likely to be driven by poor combustion situations (see Section 4.2.1.1). Under these circumstances, D/F testing during only the DRE test conditions may be appropriate instead of testing during every test condition. Even under such circumstances, EPA OSW recommends that the challenging combustion scenarios discussed in Section 4.2.2.3 be emphasized, if applicable. The combustion parameters listed in Section 4.2.2.2 should automatically be addressed, since they are typically demonstrated and limited as part of the DRE determination. D/F testing during only the DRE test conditions should be less burdensome than testing during all conditions, but still conservative.

The recommendation for D/F sampling during all test conditions (or during the DRE conditions for rapid wet quench/wet APCD configurations) is a general guideline. However, some facilities and permit writers may be faced with situations that are not addressed by this general guideline. For example, DRE and SRE testing may already have been conducted in advance of the risk burn, or

simultaneous stack determinations for consolidated testing may not be possible. These and other situations call for decisions regarding the specific combustion conditions to be demonstrated (in addition to the conditions which are conducive to downstream formation discussed in Section 4.2.1). Therefore, this guidance recommends that the challenging combustion scenarios described in Section 4.2.2.3 (if applicable) be preferentially targeted for D/F testing and that, as appropriate, permit limits for the Section 4.2.2.2 combustion parameters be established based on D/F testing conducted under these challenging combustion scenarios. In addition, EPA OSW recommends that a facility-specific review of trial burn and historical operating data be performed to determine whether the challenging combustion scenarios correlate with other operating or feed parameters. If so, it is recommended that the correlating parameters be demonstrated during the testing, and it may be appropriate to limit those parameters in the permit in addition to, or possibly in lieu of, the combustion parameters listed in Section 4.2.2.2. Caution should be exercised to ensure that targets during the D/F testing for the Section 4.2.2.2 combustion parameters are not substantially different from those demonstrated during the DRE test.

Finally, it is important to recognize that some combustion units operate under extremely steady-state conditions, at temperatures and residence times that should routinely ensure good combustion. Challenging combustion situations, such as those described in Section 4.2.2.3, do not occur. For example, a liquid injection incinerator feeding a single high-British thermal unit (Btu) waste stream may sustain very constant, high temperatures. Combustion conditions may not fluctuate at all, and carbon monoxide may be near zero. Ideally, logistics will favor combining the D/F testing with the DRE conditions (in addition to performing D/F testing during the conditions conducive to downstream formation per Section 4.2.1, if applicable). If so, then the combustion parameters listed in Section 4.2.2.2 should automatically be addressed, since they are typically demonstrated and limited as part of the DRE determination. However, if combined testing is not possible, then consideration may be given to limiting the D/F testing to only those test conditions which are conducive to downstream formation (if applicable), and/or testing under normal combustion conditions, where appropriate (see Section 3.3.2.2). EPA OSW also recommends that historical operating data for the appropriate combustion parameters be reviewed to verify that the facility maintains steady-state operations with very few fluctuations. Demonstration of absolute maximum or minimum values for the combustion parameters listed in Section 4.2.2.2 during D/F testing may

be less critical for steady-state operations. In lieu of specific permit limits for the parameters listed in Section 4.2.2.2, periodic reporting to confirm continued absence of transients may be appropriate. When D/F testing cannot be performed in conjunction with the DRE test, caution should be exercised to ensure that targets during the D/F testing for the combustion parameters listed in Section 4.2.2.2 are not substantially different from the levels demonstrated during the DRE test.

Combustion conditions can play a key role in minimizing the formation of D/F precursors, and thus, in potentially minimizing D/F emissions. Maintenance of good combustion conditions to limit organic precursors and soot is repeatedly cited as a prerequisite necessary for achieving low D/Fs (Hasselriis 1987; Kilgroe and others 1990; Kilgroe 1996; Prescott 1996; Berger and others 1996; Gullett and Raghunathan 1997; EPA 1999e).

Substantial information exists to indicate that D/F emissions can be quite high when combustion parameters are not optimized. A majority of the work documenting the influence of combustion quality has been performed on municipal waste combustor systems. Gullett and Raghunathan observed substantial increases in D/F emissions under conditions of poor combustion and carbon monoxide levels greater than 2,000 parts per million (ppm) (Gullett and Raghunathan 1997). Buekens and Huang cite studies where poor combustion situations caused order-of-magnitude D/F increases over those observed during normal combustion (Buekens and Huang 1998). Berger describes a correlation between high D/F emissions and high total hydrocarbon emissions (Berger and others 1996). Prescott documents order-of-magnitude reductions in D/Fs through the use of good combustion control (Prescott 1996), and Hasselriis found that the optimum combustion conditions for minimizing dioxins and furans are closely related to those which minimize carbon monoxide emissions (Hasselriis1987).

Because order-of-magnitude increases in D/F emissions have been observed under certain combustion situations, it is important to ensure that potentially high-emitting operating modes are not overlooked when planning the risk burn. Therefore, the recommendations in this section focus on identifying and demonstrating challenging combustion situations for D/F testing. However, a facility is not precluded from showing, on a site-specific basis, why a less conservative approach may be warranted, or from following the procedures in Section 3.3.2.2 to show that D/F testing should be performed at normal conditions to

better represent the risk over a facility's operating life.

Targeting specific combustion conditions for D/F testing can be extremely challenging, because the relationship between individual combustion parameters and D/F emissions is not necessarily intuitive or readily demonstrated. Buekens and Huang explain that D/F formation in combustion processes is influenced by a number of combustion parameters simultaneously, and is therefore regarded as a multi-variate process (Buekens and Huang 1998). Key parameters are likely to vary by facility, and the key parameters may or may not be those identified in this guidance. For example, oxygen concentration is not specifically addressed during many trial burns, and often varies considerably between test conditions if excess air is used to simultaneously achieve minimum combustion temperature and maximum combustion gas velocity. Although studies show that D/F emissions may be affected by oxygen levels, contradictory conclusions have been reached regarding the specific relationship (Buekens and Huang 1998). Buekens and Huang postulate that different combustors may exhibit different behaviors with varying oxygen, and that there may not be a universally applicable correlation. The uncertain relationship between oxygen and D/Fs is just one example of the difficulty in predicting how different operating scenarios may affect D/F emissions.

Because of the inherent uncertainties involved in correlating D/F emissions and individual combustion parameters, it is recommended that D/F emissions be determined during *all* planned test conditions (e.g., DRE and SRE conditions) whenever possible. By characterizing D/Fs over the entire range of combustion conditions, a facility can minimize the possibility of inadvertently omitting combustion situations that may play a key role in D/F formation. In addition, the data collected during multiple conditions can be analyzed for trends to determine which combustion parameters may need to be limited in the RCRA permit to control D/F emissions. EPA OSW recommends that the challenging combustion scenarios discussed later in Section 4.2.2.3 be represented during the testing (if applicable). The challenging combustion situations described in Section 4.2.2.3 include: 1) transient conditions; 2) operation with containerized or batch feeds; and 3) high carbon monoxide situations. The combustion parameters identified in Section 4.2.2.2 should automatically be addressed when D/F testing is performed during all planned test conditions, since these parameters are typically demonstrated and limited as part of the DRE determination. The combustion parameters listed in Section 4.2.2.2 include: 1) minimum primary and secondary combustion chamber exit temperatures; 2) maximum combustion gas velocity; 3) maximum waste feed rate at each feed location; 4)

limitations on waste feed composition and batch feeds; and 5) maximum flue gas carbon monoxide and/or total hydrocarbon concentrations.

At the beginning of Section 4.2.2.1, several situations were identified where it may not be possible (or even necessary) to perform D/F sampling during every test condition. For example, DRE and SRE testing may have already been conducted in advance of the risk burn. In these situations, EPA OSW recommends that the challenging combustion scenarios described in Section 4.2.2.3 be preferentially targeted for D/F testing (if applicable). Again, these scenarios include: 1) transient conditions; 2) operation with containerized or batch waste feeds; and 3) high carbon monoxide (greater than 100 ppm) situations. These scenarios are appropriate to target because of the increased potential for localized oxygen deficiencies and carbon monoxide/total hydrocarbon spikes. Numerous test programs have established that D/Fs can be high when oxygen is insufficient or when carbon monoxide/total hydrocarbon concentrations are high (Hasselriis 1987; Kilgroe and others 1990; Harris and others 1994; Kilgroe 1996; Berger and others 1996; Gullett and Raghunathan 1997; Buekens and Huang 1998). As appropriate, EPA OSW recommends that permit limits for the Section 4.2.2.2 combustion parameters be established based on D/F testing conducted under these challenging combustion scenarios. In addition, it is recommended that a facility-specific review of trial burn and historical operating data be performed to determine whether the challenging combustion scenarios correlate with other operating or feed parameters. If so, then EPA OSW recommends that the correlating parameters be demonstrated during the testing, and it may be appropriate to limit them in the permit in addition to, or possibly in lieu of, the combustion parameters listed in Section 4.2.2.2.

At some facilities, the challenging combustion scenarios identified in Section 4.2.2.3 may not occur. Although challenging combustion situations can clearly increase D/Fs, there is little information regarding the difference between "better" and "best" combustion. One study shows that stack concentrations of D/Fs may be somewhat independent of combustion conditions (except in instances of very poor combustion) provided that downstream formation of D/Fs is limited or controlled (Kilgroe 1996). This study would seem to indicate that, for steady-state systems, demonstration of absolute minimum or maximum values for the Section 4.2.2.2 combustion parameters during the D/F testing may be less critical. Although demonstration of these control parameters can ideally be accomplished by combining the D/F testing with the DRE demonstration (which is preferred whenever possible), consideration may be given for some steady-state systems to limiting the D/F testing to only those test conditions which are conducive to

downstream formation per Section 4.2.1 (if applicable), and/or testing under normal conditions provided the facility meets the criteria in Section 3.3.2.2. Periodic reporting to confirm the continued absence of transients may be appropriate in lieu of establishing specific permit limits for the Section 4.2.2.2 combustion parameters.

4.2.2.2   Combustion Parameters

Recommendation -- *To assure combustion quality and minimize D/F precursors, EPA OSW recommends that the following combustion parameters be demonstrated during D/F testing and controlled during subsequent facility operation, consistent with the recommendations in Section 4.2.2.1:*

- *C   Minimum PCC and SCC combustion temperatures;*

- *C   Maximum combustion gas velocity as an indicator of residence time;*

- *C   Maximum waste feed rate for each feed location;*

- *C   Limitations on waste feed composition and batch /containerized feeds;*

- *C   Maximum flue gas carbon monoxide and/or total hydrocarbon concentrations.*

If other potentially significant parameters are identified based on a facility-specific review, then it is recommended that those parameters be demonstrated during D/F testing and possibly limited in the permit in addition to, or possibly in lieu of, the parameters listed above.

The relationship between these parameters and combustion quality has been discussed at length in other EPA documents (EPA 1989 and 1999e), and is not repeated here. Further discussion on waste feed composition, as well as on limitations for batch or containerized feeds, can be found in Section 4.2.2.3.1, Section 4.2.2.3.2, and Section 4.2.3 of this document. Controls may also be established on the waste firing system to ensure that burners are operated efficiently and in a manner consistent with manufacturer specifications (EPA 1989 and 1999e).

It is important to keep in mind that the most influential combustion parameters may not always be the ones listed above. EPA OSW recommends that a facility-specific review of test burn and historical operating data be performed to determine the potential significance of other operating or feed parameters, especially for the challenging combustion scenarios described in Section 4.2.2.3. If other potentially significant parameters are identified, then it is recommended that they be demonstrated during D/F testing and possibly limited in the permit in addition to, or possibly in lieu of, the parameters listed in this section as necessary to protect human health and the environment.

The importance of a facility-specific review to determine the significant parameters affecting combustion quality is illustrated by a situation documented by Branter (Branter and others 1999). In an initial test effort involving containerized waste feeds, the facility did not adequately control downstream D/F formation (i.e., the heat exchanger outlet temperature was not maintained as low as possible). For the two test conditions conducted at a high heat exchanger outlet temperature, the D/F yields were substantially greater at *maximum* PCC combustion temperatures than at minimum PCC combustion temperatures. This result seems counter-intuitive at first, and illustrates the importance of analyzing trial burn or historical operating data on a case-by-case basis.

Although the phenomenon described by Branter initially seems counter-intuitive, it may be explained by the work of Lemieux (Lemieux and others 1990). Lemieux showed that containers may be more rapidly heated and ruptured at higher PCC temperatures and higher kiln rotation speeds. Evolution of waste gases from the containers can exceed the rate at which stoichiometric oxygen can be supplied, resulting in increased organic emissions, or "puffs." Lower temperatures may lead to more gradual rupture of waste containers, and less disruptive organic puffs. This situation is discussed further in Section 4.2.2.3.2. In the situation documented by Branter (Branter and others 1999), the higher PCC temperature test may have been associated with more rapid container heating and larger organic puffs, providing more organic precursors for downstream D/F formation at the high quench outlet temperature. Despite the higher PCC temperature and CO below 100 ppm (hourly rolling average corrected to 7% oxygen), this unit operating at a high PCC temperature also failed DRE. The unit passed DRE and experienced reduced D/F emissions during the lower PCC temperature run. It is interesting to note that, once downstream quench temperatures were lowered, D/F emissions were reduced and appeared to be independent of PCC temperature.

Section 4.2.2.3   **Challenging Combustion Scenarios**

Section 4.2.2.1 recommends D/F sampling during *all* test conditions whenever possible (or during the DRE conditions for rapid wet quench/wet APCD configurations). However, some facilities and permit writers may be faced with situations that are not addressed by these general guidelines. DRE and SRE testing may have already been conducted in advance of the risk burn, or simultaneous stack determinations for consolidated testing may not be possible. These and other situations call for decisions regarding the specific combustion conditions to be demonstrated. Therefore, this guidance recommends that the following combustion situations (if applicable) be preferentially targeted for D/F testing:

- C   Transient conditions;

- C   Combustion of containerized or batch wastes;

- C   Operation at high carbon monoxide levels, for units with carbon monoxide limits greater than 100 ppm.

In all of these situations, there may be an increased potential for incomplete combustion products to act as D/F precursors and increase D/F emissions. The remainder of this section provides additional information on these scenarios.

4.2.2.3.1   **Transient Conditions**

> ***Recommendation --*** *If a combustion unit normally operates under transient conditions, then EPA OSW recommends that this form of operation be represented during D/F testing. It is recommended that the facility-specific feed or operating conditions causing the transients be identified and targeted for the risk burn. The need for permit conditions to limit transients after the risk burn may be necessary to protect human health and the environment and should generally be considered taking into account the risk burn emissions data and the facility's operating history.*

Transient combustion conditions are usually indicated by recurring spikes in combustion parameters, especially combustion temperatures, combustion chamber pressure, carbon monoxide, or total

hydrocarbons. Routine spikes should generally be emphasized for the risk burn (i.e., spikes which may occur as often as several times per hour on an ongoing basis). Upsets are not encompassed by the term "transient," and are generally not represented during the risk burn unless there is a specific agreement reached between the facility and permit writer.

Transient spikes indicate potential changes in combustion quality that may increase D/F emissions. Raghunathan documented an order-of-magnitude D/F increase during a test run where a few significant CO spikes occurred, even though the average CO concentration for the 3-hour test run was maintained well below 100 ppm (Raghunathan and others 1997a). Berger describes a correlation between high D/F emissions and total hydrocarbon spikes (Berger and others 1996).

If a combustion unit normally operates under transient conditions, then it is recommended that this form of operation be represented during D/F testing. The permit writer should review historical operating data to determine whether a facility experiences routine transients. If so, EPA OSW recommends that the waste feed or operating conditions that cause the transients be determined. The feeds or operating conditions causing transients represent candidate conditions for D/F testing. Particular attention should generally be given to data indicating transients for combustion temperatures, combustion chamber pressure, carbon monoxide, and total hydrocarbons. Instantaneous data will be more useful in identifying transients than rolling average data, which inherently dampens spikes.

Batch feeds can cause transients, and are discussed separately in Section 4.2.2.3.2. However, other wastes can cause transients if they are not blended properly, or if they are treated in a unit that is not designed to accommodate particular waste types. Adequate blending or mixing of waste to minimize variations in heating value, volatility and moisture content can reduce combustion transients associated with improper feed conditions (Kilgroe 1996). Examples of wastes that can cause transients if handled improperly include:

- C Stratified or highly viscous liquids and sludges;

- C Aqueous or low heating value liquids;

- C Liquids with a high percentage of solids;

C   Highly chlorinated wastes;

C   Low heating value solids and sludges;

C   Wastes with a high moisture content; and

C   Batch feeds with high moisture, volatility, or instantaneous oxygen demand.

During D/F testing, EPA OSW recommends that the facility treat actual wastes (and not surrogate wastes synthesized from pure compounds) whenever possible. Candidate wastes should generally be selected based upon a review of the wastes handled at a particular facility, with special consideration given to those wastes burned at commercial facilities due to their variation and complexity.

4.2.2.3.2   Containerized or Batch Wastes

Recommendation -- When a facility feeds containerized or batch wastes, EPA OSW recommends that D/F testing be performed while operating under simulated "worst-case" containerized or batch feeding conditions. It may be appropriate to spike actual wastes to maximize the volatility and oxygen demand of each batch charge.

EPA OSW recommends that maximum total waste feed rate to the batch feed system (e.g., lb/hr) be maintained as part of the "worst-case" test demonstration. The individual batch size and feeding frequency will depend on the feeding practices at a particular facility.

During the risk burn, EPA OSW recommends that the air flow to the combustion unit generally be adjusted to minimize excess oxygen at the location in the combustion chamber where the batch is fed. In addition, the testing should generally be performed at higher kiln temperatures and higher kiln rotation speeds.

In most cases, permit limits for maximum total waste feed rate to the batch feed system (e.g., lb/hr) and maximum flue gas carbon monoxide/total hydrocarbon concentrations will be established to meet regulatory requirements (see Section 1.3). Additional permit limits may be necessary to protect human health and the environment, taking into account whether preventive controls are

necessary to assure that good combustion practice is maintained. Preventive controls may be
needed if operating extremes for the batch feed system cannot be adequately represented during the
risk burn, or if the facility has historically experienced frequent operational upsets or waste cutoffs
due to batch feeds.

If preventive controls are needed, other permit limitations which might be considered include: 1)
maximum batch size; 2) maximum batch charge heat content; 3) maximum batch feeding frequency;
4) minimum oxygen concentration at the location where the batch is fed; 5) maximum kiln
temperature; 6) maximum kiln rotational speed; and 7) limitations on waste volatility, composition,
or heat content.

Overcharging conditions can occur when containerized or batch wastes are fed to a combustion unit, especially if waste parameters and feeding practices are not closely matched to the unit design. When highly combustible or volatile wastes are exposed to the high temperatures in a combustion chamber, a surge of waste vapors rapidly evolves from the batch. This surge can deplete local oxygen, causing formation of fuel rich gas pockets that may escape the combustor without being adequately oxidized. This situation is often described as "puffing." Stack emissions may be affected, depending on whether the organics are destroyed elsewhere (such as in an afterburner).

Transient puffs arising from batch feed operations are well documented based on measurements conducted at the PCC exit of both pilot scale and full scale incinerators (Linak and others 1987; Cundy and others 1991; Lemieux and others 1990). At a pilot-scale facility, Linak documented PCC exit total hydrocarbon levels in excess of 10,000 ppm during very intense puffs, and performed chemical analysis to show that the puffs can contain numerous hazardous compounds, even though adequate DREs (>99.99%) may be achieved (Linak and others 1987). In several of the measurements, D/Fs were also formed at part-per-trillion levels. Both D/Fs and other chlorinated hazardous organics were formed most readily when chlorinated compounds were fed together with high heating value materials, such as toluene, which caused high magnitude, high intensity puffs. Linak observed that higher kiln temperatures and rotation speeds adversely affect puff intensity, because de-volatilization rates are enhanced by the increased temperatures and bed mixing. This observation has been confirmed by Lemieux (Lemieux and others 1990), and Branter (Branter and others 1999) has documented higher D/F emissions at higher PCC temperatures for a full-

scale facility (see the discussion in Section 4.2.2.2).

Because the soot and chlorinated organic precursors from transient puffs can affect D/F emissions, this guidance recommends that the risk burn be performed while operating under simulated "worst-case" batch feeding conditions (i.e., conditions that maximize precursor generation) to ensure that D/F emissions are not under-estimated for the risk assessment. Historical information on operating trends and AWFCO events should generally be reviewed in an effort to determine which batch characteristics are most likely to cause transients for a particular facility. Some batch-charged and containerized wastes can volatilize rapidly, causing an instantaneous release of heat and gases that completely consume the available oxygen. This rapid volatilization results in a momentary oxygen-deficient condition that can result in poor combustion. Conversely, if too large a batch of aqueous waste or wet soil is fed, there is danger that the batch can instantaneously quench temperature.

During the risk burn, EPA OSW recommends that actual wastes be spiked as necessary to maximize the volatility and oxygen demand of each batch charge. This maximization can be achieved by spiking with low boiling point/low latent heat of vaporization organics (preferably chlorinated), together with high heating value organics that have a high stoichiometric oxygen demand (Linak and others 1987; Wendt and others 1990; Cundy and others 1991). In rotary kilns, spiking compounds may be fed in bottles placed within the batch (instead of sorbed onto a solid matrix) to maximize the rate of volatilization.

The individual batch size and feeding frequency to be targeted for the risk burn should generally be based on the feeding practices at a particular facility. The "total waste feed rate" for the batch feed system (e.g., lb/hr) is a target combustion parameter (see Section 4.2.2.2) and should generally be maximized anyway. However, risk burn goals for individual batch size and feeding frequency may conflict (i.e., a facility may not be able to simultaneously feed their largest batch at their highest frequency). For the most part, the work of Lemieux suggests that larger batches fed less frequently will be worse than smaller batches fed more frequently at a given total feed rate (Lemieux and others 1991). In defining maximum batch size, the "maximum batch charge heat content" (maximum Btu/charge) is just as important as (and perhaps more important than) total mass.

The test plan for a batch-fed facility should generally include a description of the procedures used to

maintain adequate oxygen while feeding batch or containerized wastes. During the risk burn, the air flow to the combustion unit should generally be adjusted to minimize excess oxygen at the location in the combustion chamber where the batch is fed. In addition, the testing should generally be performed at higher kiln temperatures and rotation speeds, since these parameters have been shown to exhibit a strong correlation with puff intensity. Demonstration of high kiln rotation speed may be less imperative if spiking compounds are added in bottles to the batch instead of sorbed to a solid matrix, since this spiking method should generally assure a high volatilization rate. Multiple test conditions may be necessary to demonstrate high kiln temperatures, as well as the minimum temperatures recommended in Section 4.2.2.2. For some incinerators, a worst-case test may involve maximum PCC temperatures demonstrated in conjunction with minimum SCC temperatures.

The effect of transient puffs on stack emissions may vary substantially from facility to facility. Variations may depend on: 1) unit design and operation (including size, presence of an afterburner or SCC, and fuel-to-air controls); 2) waste characteristics (including volatility, instantaneous oxygen demand, heating value, and moisture content); and 3) feeding practices (including batch size, feeding frequency, feed location, excess oxygen, and the oxygen demand of batch feeds versus the oxygen demand of other fuels). Historically, batch feed practices at some facilities have caused DRE failures, upset conditions, carbon monoxide spikes, and excessive waste feed cutoffs. At other facilities, batch feeds do not appear to significantly affect either emissions or day-to-day operations.

The variable effect of batch feeds on emissions and day-to-day operations suggests that a facility-specific evaluation may be necessary to determine appropriate permit restrictions after the risk burn. In most cases, permit limits for maximum total waste feed rate to the batch feed system (e.g., lb/hr) and maximum flue gas carbon monoxide/total hydrocarbon concentrations will be established anyway to ensure compliance with RCRA and MACT regulatory performance standards (see Section 1.3). These parameters also assure combustion quality and minimization of D/F precursors, as discussed in Section 4.2.2.2.

Although total waste feed rate to the batch feed system (e.g., lb/hr) will be limited to meet specific RCRA or MACT regulatory requirements, this limitation may not be adequate for all situations because a facility can theoretically feed a very large batch on a very infrequent basis. A batch feed rate limit may be sufficient when it is based on a worst-case test, and when other system constraints are present (for example,

maximum batch size may be limited by the physical constraints of the batch feed system). However, in some cases, it may be preferable to augment a pound-per-hour feed rate limit with additional restrictions on maximum batch size or maximum batch charge heat content.

Carbon monoxide/total hydrocarbon levels have routinely been used to characterize combustion perturbations associated with batch feeds (Linak and others 1987; Cundy and others 1991; Lemieux and others 1991). Establishing limits for these parameters in conjunction with a "worst-case" batch feed test may be sufficient for assuring that ongoing operations are protective at some facilities. However, carbon monoxide or total hydrocarbon monitoring alone may not be adequate for all batch feed operations. Because oxygen depletion can occur very rapidly due to batch overcharging, carbon monoxide/total hydrocarbon levels may exceed the permit limit before corrective action can be initiated. For some operations, additional preventive measures may be necessary to protect human health and the environment by assuring that good combustion practice is maintained.

Other permit limitations which might be considered if preventive measures are needed include: 1) maximum batch size; 2) maximum batch charge heat content; 3) maximum batch feeding frequency; 4) minimum oxygen concentration at the location where the batch is fed; 5) maximum kiln temperature; 6) maximum kiln rotation speed; and 7) limitations on waste volatility, composition or heat content. Implementation of minimum oxygen limits for rotary kilns can sometimes be difficult, due to potentially significant gas-phase stratification (Cundy and others 1991). If gas-phase stratification is a problem, alternative monitoring locations may need to be considered.

The need for preventive controls should generally be determined based on a review of test conditions, emissions data, and the facility's operating history. There may be less need for preventive controls if operating extremes for the batch feed system can be adequately represented during the risk burn (or if emissions appear to be unrelated to batch feed operations), and if the facility routinely operates with few operational upsets or waste cutoffs related to batch feeds. Conversely, there may be more justification for establishing preventive controls on the batch feed system if operating extremes for the batch feed system cannot be adequately represented during the risk burn, or if the facility experiences frequent operational upsets or waste cutoffs due to batch feeds.

4.2.2.3.3   High Carbon Monoxide

> *Recommendation --* EPA OSW recommends that units with carbon monoxide limits greater than
> 100 ppm perform D/F emissions testing while carbon monoxide levels are maximized.

When D/F emissions data are evaluated by normalizing the data based on APCD inlet temperature and
carbon monoxide, low carbon monoxide levels (less than 100 ppm) are found to be associated with very
low D/F emissions (less than 1 ng/dscm on a total basis) (EPA 1994c; Harris and others 1994). For
carbon monoxide levels greater than 100 ppm, temperature-normalized dioxin emissions are found to be
significantly higher (in the range of 10 to 100 ng/dscm on a total basis). This observation suggests that
units with carbon monoxide limits *greater than* 100 ppm should generally perform D/F testing under
conditions that maximize carbon monoxide levels.

4.2.3   Feed Composition

In addition to the physical waste characteristics described in Sections 4.2.2.3.1 and 4.2.2.3.2 that may
contribute to poor combustion, there are several chemical feed characteristics that have been evaluated with
respect to their potential influence on D/F emissions. These characteristics include chlorine concentration,
the presence of metals (such as copper, iron, and nickel) that can act as catalysts for D/F formation, the
presence of D/F precursors (such as chlorobenzenes and chlorophenols), and the presence of D/F inhibitors
(such as sulfur, calcium hydroxide, and ammonia). Each of these is discussed below.

4.2.3.1   Chlorine

> *Recommendation --* For D/F testing, EPA OSW recommends that chlorine feed rates be maintained
> at normal levels (i.e., chlorine should not be biased low). Permit limits on total chlorine feed rate
> generally should not need to be established based on the risk burn.

While the presence of chlorine is a necessary prerequisite for D/F formation, there does not appear to be a
direct correlation between the level of chlorine in the feed and the level of D/Fs in the flue gas at full-scale
combustion facilities. The American Society of Mechanical Engineers (ASME) (Rigo and others 1995)

analyzed over 1,700 test results with chlorine feed concentrations ranging from less than 0.1 percent up to 80 percent, and found no statistically significant relationship between D/F emission rates and chlorine concentration. Gullett provides a possible explanation for the poor correlation (Gullett and others 2000a). Obviously, no D/Fs can be formed in the complete absence of chlorine. However, extremely low concentrations of chlorine may be sufficient to form D/Fs at the trace levels of concern. An excess of chlorine does not necessarily yield greater quantities of D/Fs, and other parameters, such as APCD inlet temperature, appear to have a more significant influence on D/F yields.

Based on this information, there does not appear to be a need to demonstrate maximum chlorine feed rates during the risk burn, or to establish specific feed rate limits on total chlorine in the permit based upon the D/F testing. However, it is reasonable to expect that facilities will maintain normal levels of chlorine for the D/F testing (i.e., chlorine should generally not be biased low). Chlorinated wastes are preferred over non-chlorinated wastes for the risk burn, where the choice exists. In this guidance, the term "chlorine" refers to total chlorine from all sources, including both organic and inorganic forms.

4.2.3.2 Metal Catalysts

> ***Recommendation --*** *EPA OSW recommends the use of wastes or other feed materials containing copper over feeds without copper during the D/F testing, where the choice exists. However, specific permit limits on copper (or other catalytic metal) feed rates based upon the D/F testing are generally not anticipated to be necessary to protect human health and the environment.*

Abundant pilot-scale and fundamental research has shown that certain metals, such as copper, may catalyze the formation of D/Fs (see Section 4.1). However, there does not appear to be a direct correlation between the level of copper in the feed and the level of D/Fs in the flue gas at full-scale combustion facilities. Copper spiking during full-scale testing of a cement kiln showed little or no influence on D/F emissions (Lanier and others 1996), although the testing may have been conducted in a system that was influenced by other, more dominant factors.

Luijk has shown that copper plays a competing role in both the formation *and destruction* of D/Fs (Luijk and others 1994). Copper contributes to *de novo* synthesis of D/Fs, but it also catalyzes their oxidative

destruction. Luijk and others hypothesize that CuCl$_2$ levels in the ppm range (no greater than the levels normally observed in municipal waste combustion fly ash) may offer optimum conditions for the formation of D/Fs.

Based on this information, there does not appear to be a need to spike copper during the D/F testing, or to establish specific permit limits on copper (or other catalytic metals). However, EPA OSW recommends the use of wastes or other feed materials containing copper over feeds without copper, where the choice exists.

4.2.3.3 D/F Precursors

Recommendation -- If a facility burns wastes containing significant quantities of D/F precursors, EPA OSW recommends that these wastes be used for D/F testing, rather than wastes without precursors. Although specific D/F precursor feed rate limits in the permit are not anticipated to be necessary to protect human health and the environment, it may be appropriate to consider a permit condition requiring waste profile tracking to determine whether increased quantities of precursor wastes warrant retesting.

The role of organic precursors with respect to D/F formation is discussed in Section 4.1. Some waste combustors that burn wastes containing D/F precursors, including chlorobenzenes, chlorophenols, and PCBs, have been shown to have high D/F emissions (for example, see the discussion regarding Source ID No. 330 in Section 4.2.1.1). EPA has compared a limited number of facilities that feed known D/F precursors to those that do not feed D/F precursors (EPA 1996a). This limited comparison suggested no strong correlation between the level of precursors and D/F formation; however, the issue has not been examined in detail.

Since higher D/F emissions have been observed at some facilities burning D/F precursors, wastes containing significant quantities of D/F precursors are generally preferred over wastes without precursors for D/F testing. Specific feed rate limits on D/F precursors in the permit generally should not be necessary. However, it may be necessary for protection of human health and the environment to include a permit condition requiring waste profile tracking to determine whether increased quantities of precursor wastes warrant retesting.

4.2.3.4   D/F Inhibitors

> *Recommendation --* *In reviewing the D/F test protocol, EPA OSW recommends that the permit*
> *writer verify that the facility will not burn a high sulfur waste or fuel in quantities that bias the S/Cl*
> *feed ratio above normal. At S/Cl molar feed ratios approaching 0.3 or greater, it may be*
> *appropriate for protection of human health and the environment after the risk burn to require waste*
> *and fossil fuel tracking to ensure that a minimum S/Cl ratio is maintained on an ongoing basis. If*
> *sulfur or other D/F inhibitors are intentionally added to the system to achieve D/F control, then*
> *EPA OSW suggests that the recommendations in Section 4.2.5 be followed.*

The role of SO_2 in suppressing D/F formation is discussed in Section 4.1. D/F inhibitors, such as sulfur,
have been commercially marketed as feed stream additives to control D/F emissions.   These same
compounds may naturally be present in fossil fuels (such as coal) or hazardous waste fuels.

Numerous pilot-scale and full-scale tests on municipal solid waste combustors have proven that D/F
emissions reductions can be achieved via coal co-firing to increase SO_2 or SO_2 injection (Raghunathan and
Gullett 1996; Gullett and Raghunathan 1997; Raghunathan and others 1997a; Buekens and Huang 1998;
Gullett and others 2000b). The suppression effect is well documented when sulfur is present at levels
nearly stoichiometric to the chlorine in the feed (i.e., S/Cl molar feed ratio of approximately 1:1). Ullrich
has also shown that sulfur levels well below stoichiometric ratios with chlorine can reduce dioxin formation
measurably in a full-scale hazardous waste incinerator (Ullrich and others 1996). Significant decreases in
D/F emission rates were observed at sulfur-to-chlorine molar ratios as low as 0.3 in the feed (Ullrich and
others 1996).

In reviewing the D/F test protocol, EPA OSW recommends that the permit writer verify that the facility
will not burn a high sulfur waste or fuel in quantities that bias the S/Cl feed ratio above normal. The
particular S/Cl ratio that begins to cause a D/F suppression effect is likely to be system specific, and D/F
suppression may be influenced by other, more significant facility-specific variables (Gullett and others,
2000b). However, the results from Ullrich suggest that S/Cl molar feed ratios above approximately 0.3,
considering both waste and fossil fuel inputs, should generally be viewed with caution (Ullrich and others
1996). If S/Cl molar ratios approach 0.3 or greater during the risk burn, then waste and fossil fuel tracking

conditions in the permit may be necessary to protect human health and the environment by ensuring that a minimum S/Cl ratio is maintained on an ongoing basis.

This discussion primarily applies to situations where naturally-occurring sulfur may be introduced to the combustor with fossil fuels, or when sulfur is normally present in the waste fuel. In some cases, sulfur or other D/F inhibitors are intentionally added to the combustion system to achieve D/F control. For these situations, EPA OSW suggests that the recommendations in Section 4.2.5 be followed.

4.2.3.5   Dioxin-Containing Wastes

Recommendation -- If a facility burns dioxin-containing wastes (such as F020, F021, F022, F023, F026, F027, F032, F039 or K099), EPA OSW recommends that those wastes be represented during D/F testing. Specific permit limits on D/F contributions from these wastes may be necessary to protect human health and the environment by ensuring that dioxin/furans are not being burned in higher amounts than those represented during the risk burn and found to be protective.

For many combustion units, D/F emissions are primarily influenced by formation within the combustion system. However, a few hazardous waste combustors burn dioxin-containing wastes (such as F020, F021, F022, F023, F026, F027, F032, F039 or K099), and D/F emissions from those units may be significantly affected by survival of trace D/Fs introduced with the waste feed (even at an adequate level of DRE). When a facility burns these dioxin-containing wastes, the potential waste feed D/F contribution to total D/F emissions should generally be accounted for in the risk burn and risk assessment.

Ideally, the waste feed D/F contribution to total D/F emissions can be accounted for by feeding dioxin-containing wastes during the risk burn to achieve a maximum D/F input. After the risk burn, specific permit limits on waste feed D/F contributions from F020, F021, F022, F023, F026, F027, F032, F039 or K099 wastes may be necessary to protect human health and the environment by ensuring that D/Fs are not subsequently burned in higher amounts than those represented during the risk burn and found to be protective.

If dioxin-containing wastes are not available for the risk burn, then the D/F emissions measured during the

risk burn will only represent the D/Fs formed within the combustion system. In this case, it may be necessary to approximate a potential waste feed D/F contribution based on the maximum anticipated D/F feed input and the applicable DRE. Dioxin-listed wastes, including F020, F021, F022, F023, F026, and F027, are required by the RCRA and MACT regulations to be burned in a 99.9999% DRE combustion unit. Other dioxin-containing wastes, such as F032, may be burned in a 99.99% DRE combustion unit. A total D/F emissions estimate may be developed for the risk assessment by calculating the residual D/F remaining after 99.99% or 99.9999% DRE, and then adding that value to the D/F emissions measured during the risk burn (i.e., the D/Fs formed within the combustion system).

When waste feed D/F contributions are approximated, it is recommended that follow-up testing to confirm D/F emission levels be planned to coincide with receipt of an appropriate dioxin-containing waste shipment. A D/F emissions approximation is uncertain in that it cannot reflect potential differences between the congener profile (the TEQ) of the waste and resulting emissions, or the potential for waste D/F contributions to overload D/F control systems, or the potential for partial combustion products from dioxin-containing wastes to exacerbate downstream D/F formation.

4.2.3.6   Other Factors

Other waste feed components may potentially affect D/F emissions. The presence of bromine, in particular, has been found to affect emissions of chlorinated organic PICs and D/Fs in pilot-scale experiments (Lemieux and Ryan 1998a and 1998b). Lemieux and Ryan have observed that D/F emissions can be enhanced by the addition of bromine, although there appears to be a threshold below which minimal enhancement occurs and above which significant enhancement occurs (Lemieux and Ryan 1998a). For the particular study showing these effects, this threshold appeared to lie in a range of Br/Cl molar feed ratios between 0.1 and 0.5.

Although the effects of bromine have not been clearly established during full-scale testing, permit writers should be aware of this issue when selecting waste feeds for trial burns, particularly if the facility burns brominated waste during normal operations. Very little brominated waste is generated and few facilities burn it, but some do.

4.2.4   Hysteresis/Memory Effects

> *Recommendation -- EPA OSW recommends that the recent operating history at a facility be considered in planning the risk burn. The risk burn generally should not be performed immediately after refractory replacement or other maintenance activity involving soot removal from boiler tubes, ductwork, or other locations where soot and catalytic metals may have deposited. In addition, the risk burn generally should not be performed immediately after a period of firing high sulfur fuel or injecting sulfur additives.*

D/F emissions in full-scale combustion units can be influenced by hysteresis, or "memory effects" (Buekens and Huang 1998). Hysteresis means that deposits or residual contaminants remaining within the unit from previous operations can have an ongoing effect on emissions, even after operating or feed conditions have changed. Raghunathan has shown that soot deposits from periods of inefficient combustion can enhance subsequent D/F yields, with the yields decaying over time (Raghunathan and others 1996). Combined soot-copper deposits cause more D/F formation than a deposit of soot or copper alone, and D/F formation from soot deposits is inhibited in the presence of sulfur dioxide (Raghunathan and others 1996 and 1997b).

Recent work by Gullett provides further insight regarding the influence of past operating conditions on D/F emissions (Gullett and others 2000b; in press). Gullett examined the effect of co-firing coal with municipal waste in a field-scale unit to determine whether sulfur in the coal would inhibit D/F formation (Gullett and others 2000b). D/F concentrations were in fact reduced up to 80 percent from co-firing coal, and past operating conditions were found to have a lingering and significant effect on D/F concentrations. Gullett concluded that the influence of past conditions on D/F levels was consistent with a D/F formation mechanism involving combustor wall deposits as sites for formation, and proposed that the effect of higher sulfur dioxide concentration from co-firing coal was to alter the deposits in a way that either reduced chlorine contact with active sites or reduced the catalytic activity of the deposits (thereby reducing ongoing D/F formation). In research involving a hazardous waste fired boiler, Gullett and others (in press) found that boiler tube deposits became a sink and source for D/F reactants (copper and chlorine), resulting in continued D/F formation and emissions long after waste co-firing ceased. From these two studies, it appears that deposits can have both a negative and positive effect on ongoing D/F emissions. Deposits

affected by sulfur dioxide can act to suppress ongoing D/F emissions, whereas deposits that serve as a sink for D/F reactants may enhance ongoing emissions.

These data suggest that the recent operating history at a facility should be considered in planning the risk burn. The risk burn should generally not be performed immediately after refractory replacement or other maintenance activity involving soot removal from boiler tubes, ductwork, or other locations where soot and catalytic metals may have deposited. In addition, memory effects can persist for at least a day, and a given test condition may continue to reflect, in part, what happened during the previous operation (Gullett 1999). Therefore, for example, EPA OSW does not recommend performing the risk burn immediately after a period of firing high sulfur fuel or injecting sulfur additives.

4.2.5   D/F Control Technologies

Some facilities may install specific D/F control technologies such as carbon injection, carbon beds, catalytic oxidizers, and D/F inhibitor technologies. If a facility uses one of these technologies, then EPA OSW recommends that key control parameters related to performance of these technologies be demonstrated during the D/F test conditions of the risk burn and limited in the permit as necessary for protection of human health and the environment. Relevant control parameters are identified in a technical support document for the hazardous waste combustor MACT standards (EPA 1999e), and are not addressed further here.

Although control technologies involving carbon can achieve reductions in stack emissions of D/Fs, permit writers should be aware that the use of carbon may sometimes *increase* total D/F synthesis when D/Fs in the solid residues are considered. Carbon has been used successfully in a variety of applications. However, carbon injection at higher temperature locations downstream of the combustor can be problematic. Schreiber reported that dioxin concentrations in cement kiln dust increased by approximately 2 orders of magnitude when carbon was injected between the kiln and ESP at operating temperatures in excess of 500 EF (Schreiber and others 1995). A similar result is documented by Ullrich, where D/F levels in the fabric filter dust increased by a factor of 100 over levels without carbon injection when carbon was injected <u>directly to</u> the fabric filter (instead of at a lower temperature location downstream of the fabric filter) (Ullrich and others 1996). The quantities of D/Fs in the fabric filter dust exceeded the quantities

removed in the stack gas by a factor of 50.

4.2.6   **Control Parameter Summary**

Although Section 4.2 presents each control parameter individually, EPA OSW recommends that the relative importance of the parameters with respect to one another also be considered. When one or two control parameters are clearly dominant for a particular system, there may be little benefit to limiting additional parameters in the permit.

Based on a review of existing information, this guidance prioritizes control parameters and conditions associated with D/F formation as primary, secondary, or tertiary. These hierarchical designations should not be considered absolute, but are intended to emphasize the relative importance of demonstrating various control parameters during D/F testing and limiting those parameters in the final RCRA permit. A summary of primary, secondary, and tertiary control parameters follows.

1. Primary control parameters are those which have shown the highest correlation with D/F emissions in full-scale tests, and which are therefore expected to dominate D/F formation and removal. EPA OSW recommends that these parameters be demonstrated during the D/F testing, and that permit writers consider whether specific quantitative limits on these parameters are necessary to protect human health and the environment. The primary control parameters are focused on surface-catalyzed D/F formation downstream of the combustion chamber, survival of trace D/Fs from waste feeds, and the use of specific D/F control technologies. Primary control parameters include:

    -     Partial wet quench temperatures;
    -     Dry particulate hold-up temperatures;
    -     Combustion parameters listed in Section 4.2.2.2, for systems that operate under the
          challenging combustion scenarios discussed in Section 4.2.2.3;
    -     Sulfur-to-chlorine molar feed ratio, unless the S/Cl ratio is well below 0.3;
    -     D/F contributions from dioxin-containing wastes;
    -     Key control parameters for specific D/F control technologies, including the
          intentional addition of sulfur as a D/F inhibitor.

2. Secondary control parameters are those that may influence D/F emissions under certain circumstances. However, there is less information indicating a direct correlation between these parameters and D/F emission rates. These parameters may or may not be appropriate to demonstrate during the D/F test, and corresponding permit terms may or may not be necessary to protect human health and the environment, depending on the significance of these parameters for a given system configuration and the presence or absence of dominant primary parameters. Secondary control

parameters include:

- Combustion parameters listed in Section 4.2.2.2, for steady-state systems that routinely maintain good combustion and are equipped with rapid wet quench/wet APCDs;
- Conditions other than combustion quality that may produce organic precursors (such as organics from raw materials in cement kilns and lightweight aggregate kilns, as discussed later in Section 4.5).

3. <u>Tertiary control parameters</u> pertain to feed composition. These control parameters have been the subject of fundamental and pilot-scale research on D/F formation, but have not routinely been correlated with D/F emissions during full-scale testing. These parameters may influence the selection of feeds for D/F testing and subsequent waste profile tracking, but it is generally not expected that specific feed rate limits in the permit will be necessary to protect human health and the environment. Tertiary control parameters include:

- Chlorine feed rates;
- Presence of D/F catalysts (such as copper);
- Presence of D/F precursors (such as chlorinated aromatics);
- Presence of naturally-occurring D/F inhibitors (such as sulfur), provided that the S/Cl molar feed ratio is well below 0.3.

4.3   D/F EMISSIONS FROM INCINERATORS

Hazardous waste incinerator designs include rotary kiln, liquid injection, fluidized bed, and fixed hearth. Incinerator designs are described in detail in a technical support document to the hazardous waste combustor MACT rule (EPA 1999f). Commercial incineration facilities typically accept hazardous wastes from a variety of generators, and the wastes fed to commercial units can be highly variable. Wastes may range from low- and high-Btu liquids, to laboratory packs, to soils contaminated with low levels of RCRA hazardous wastes. Large chemical facilities sometimes operate "captive" incinerators that treat on-site wastes, as well as wastes generated off-site by corporate affiliates. Wastes fed to a captive unit may also be highly variable, especially if the facility burns a number of wastes from different production operations without the capability to blend the wastes to a consistent specification. Some facilities operate small on-site incinerators that treat only one or two waste streams. The wastes fed to small on-site incinerators can sometimes be more predictable and/or homogeneous than those fed to commercial or captive units.

Air pollution control for hazardous waste incinerators typically involves an exhaust gas cooling step, followed by particulate matter and acid gas control. A few incinerators treat low-ash, low-halogen wastes and do not utilize any air pollution control. Exhaust gas cooling can be performed using a waste heat boiler or heat exchanger, mixing with ambient air, or injection of water into the exhaust gas. As discussed in Section 4.2.1 of this document, the procedures used for exhaust gas cooling can have a significant affect on D/F emissions.

Particulate matter and acid gas control systems for hazardous waste incinerators can generally be grouped into three categories: 1) "wet" systems; 2) "dry" systems; and 3) "hybrid wet/dry" systems (EPA 1999f). In wet systems, wet scrubbers are used for both particulate and acid gas control. These scrubbers may include venturi scrubbers, packed bed scrubbers, ionizing wet scrubbers, wet ESPs, innovative high efficiency scrubbers, or some combination of these. In dry systems, a fabric filter or ESP is used for particulate matter control. Dry scrubbing may also be utilized upstream of the dry APCD to achieve acid gas control. In hybrid systems, a dry technique (i.e., ESP or fabric filter) is used to control particulate matter (possibly in combination with dry scrubbing for acid gas control), followed by wet scrubbing for acid gas control.   Some new technologies are being developed, and several facilities are injecting activated carbon for control of D/Fs, non-D/F organics, and mercury.

D/F emissions data are available from a variety of hazardous waste incinerators. Units equipped with rapid wet quench and wet APCD systems are among the lowest-emitting sources and generally have D/F emissions below 0.4 ng TEQ/dscm. D/F emissions from units equipped with dry air pollution control components range from 0.15 to 20 ng TEQ/dscm. Systems equipped with waste heat boilers or other types of heat exchangers have D/F emissions ranging from about 1 to 40 ng TEQ/dscm (EPA 1999d).

The level of D/F emissions from incinerators may be dependent on incinerator design, APCD type, particulate hold-up temperatures, type of quench or presence of a heat recovery unit, combustion conditions, and feed composition. In summary, all of the considerations discussed previously in Section 4.2 apply to hazardous waste incinerators. The most predominant factors influencing D/F emissions from incinerators seem to be the presence of a heat recovery unit and the temperature profile of dry APCD systems.

Table 4-1 summarizes potential control parameters associated with D/F emissions from incinerators. If dry APCD equipment or heat recovery devices are present in the downstream control system, the temperature profile across these devices is recognized as a primary control parameter directly related to D/F formation (see Section 4.2.1). Demonstration of maximum post-combustion temperature is likely to coincide with SRE testing (unless the facility can adjust inlet temperature to obtain the requisite temperature profiles during DRE testing). Combustion efficiency is also a primary control parameter for D/F formation, especially for transient operations, units burning containerized wastes, or high carbon monoxide situations as discussed in Section 4.2.2. Demonstration of control parameters affecting combustion efficiency will most likely coincide with the DRE test conditions.

Facilities with more predictable, homogeneous waste feeds, few operating fluctuations, and no particulate hold-up devices may prefer to collect D/F emissions data during a risk burn conducted under normal operating conditions, as appropriate (see Section 3.3.2.2). Waste feed selection should generally be based on representative waste streams, with a preference for D/F precursors such as chlorophenols and minimal amounts of D/F inhibitors (such as sulfur).

TABLE 4-1

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM INCINERATORS AND BOILERS

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS					
Post-Combustion Conditions: See Section 4.2.1	Maximum post-partial wet quench temperature (within the range of 570-800 EF)	SRE test, unless a variable quench is used	Group A: 1 hour rolling average	Average of the test run averages	See Section 4.2.1.2
	Maximum dry ESP inlet temperature (within the range of 400-750 EF)	SRE test, unless a variable quench is used	Group A: 1 hour rolling average	Average of the test run averages	See Section 4.2.1.3
	Maximum fabric filter inlet temperature (within the range of 400-750 EF)				
	Maximum HEPA filter inlet temperature (within the range of 400-750 EF)				
	Maximum heat exchanger exit temperature (within the range of 400-750 EF)	Any test that achieves the critical temperature window	Group A: 1 hour rolling average	Average of the test run averages	See Section 4.2.1.3 Establish a *minimum* limit if the device is operated *above* the critical temperature range to prevent formation

TABLE 4-1 (continued)

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM INCINERATORS AND BOILERS

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS (Continued)					
Combustion Conditions: (*It is recommended that these parameters also be limited to control non-D/F organics, see Section 5.3*) See Sections 4.2.2 and 4.2.6 Combustion parameters are most critical for challenging combustion scenarios including: - transient operations - batch operations - high carbon monoxide operations Combustion parameters may be less critical for steady-state systems. Although demonstration of these control parameters during DRE conditions is preferred whenever possible, D/F testing at normal combustion conditions may be considered for some steady-state units.	Minimum combustion temperature, each chamber	DRE	Group A: 1 hour rolling average Record keeping and periodic reporting to confirm continued absence of transients may be appropriate in lieu of hourly average limits for some steady-state systems.	Average of the test run averages	See Section 4.2.2.2
	Maximum combustion gas velocity	DRE/SRE			
	Maximum waste feed rate, each location	DRE			Consider limits for: - maximum organic liquids to PCC - maximum aqueous liquids to PCC - maximum sludges to PCC - maximum solids to PCC - maximum batch feeds to PCC - maximum organic liquids to SCC - maximum aqueous liquids to SCC

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS (Continued)					
Combustion Conditions: (Continued):	Waste variability that could cause transients	DRE	This is not a continuously monitored parameter, but pertains to selection of wastes for testing. Conditions for waste profile tracking may be specified by the permit writer.		See Section 4.2.2.3.1 Wastes with physical properties that can cause combustion transients should be selected.
	Batch feed conditions: - see "Maximum waste feed rate, each location" - see "Maximum carbon monoxide and/or total hydrocarbons"	DRE			See Section 4.2.2.3.2 Test wastes with high volatility and oxygen demand. Other parameters that may be necessary to limit are listed in Section 4.2.2.3.2
	Maximum carbon monoxide and/or total hydrocarbons	DRE	Group A: 1 hour rolling average	Establish per applicable regulations	See Section 4.2.2.3.3
Feed Composition: See Section 4.2.3	Minimum sulfur-to-chlorine feed ratio (unless the S/Cl molar feed ratio during the test is well below 0.3)	Any test condition where a S/Cl feed ratio ≥ 0.3 is used	Group B: Feed stream analyses may be specified to monitor sulfur-to-chlorine feed ratios	Average of the test run averages	See Section 4.2.3.4
	D/F contributions from dioxin-containing wastes	Any test with dioxin-containing wastes	Group B: Feed stream analyses may be specified to monitor dioxin input	Average of the test run averages	See Section 4.2.3.5

TABLE 4-1 (continued)

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM INCINERATORS AND BOILERS

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS (Continued)					
D/F Control Technologies: See Section 4.2.5	D/F-specific control technologies include carbon injection, carbon bed, catalytic oxidizers and D/F inhibitor technologies. If one of these control technologies is used to limit D/F emissions, permit limits on key control parameters as described in a technical support document to the hazardous waste combustor MACT rule (EPA 1999e) may be appropriate.				
TERTIARY CONTROL PARAMETERS					
Feed Composition: See Section 4.2.3	Total Chlorine D/F Catalysts D/F Precursors D/F Inhibitors	These are not continuously monitored parameters, but pertain to selection of wastes and fuels for testing. Conditions for waste profile tracking may be specified by the permit writer.			Considerations are discussed in Section 4.2.3

Notes:
D/F = dioxins and furans
DRE = destruction and removal efficiency
EPA = U.S. Environmental Protection Agency

ESP = electrostatic precipitator
HEPA = high efficiency particulate air
PCC = primary combustion chamber

SCC = secondary combustion chamber
SRE = system removal efficiency

* = See Section 1.3.1 for a description of the Group A, B and C designations. Hourly rolling averaging periods are specified as examples, but other averaging periods and techniques may be considered. By establishing operating limits from the test as "the average of the test run averages," the permit writer can better ensure consistency between the manual emissions measurements and the permit. It is less desirable to establish an operating limit as "the average of the minimum (or maximum) hourly rolling averages from the three test runs," because the minimum or maximum operating extremes may only be demonstrated during a minor portion of the total stack sampling period.

4.4　　　　　　D/F EMISSIONS FROM BOILERS

Boilers recover thermal energy from combustion of hazardous waste and export the energy in the form of steam, heated fluids, or heated gases. General boiler designs are discussed in *Combustion Emissions Technical Resource Document* (EPA 1994c), and requirements for boilers burning hazardous waste are defined in 40 CFR Part 266.100 et seq. The following characteristics of a boiler are prescribed by 40 CFR Part 260 for RCRA regulatory purposes: 1) the combustion chamber and primary energy recovery section must be of integral design; 2) thermal recovery efficiency must be at least 60%; and 3) at least 75% of the recovered energy must be exported (i.e., not for internal boiler use). Hazardous waste is most commonly burned in firetube boilers, although watertube boilers are used in some cases. Most boilers treating hazardous waste are on-site units at chemical production facilities. Many oil- and gas-fired boilers burn low-ash, low-halogen wastes and are not equipped with any air pollution control. Some boilers utilize wet scrubbing or fabric filtration, and a few units (primarily coal-fired devices) are equipped with ESPs.

The database of D/F emissions from hazardous waste burning boilers is not as extensive as for incinerators and cement kilns (EPA 1994c). EPA provides data on two boilers equipped with ESPs indicating average D/F emissions less than 0.03 ng TEQ/dscm (EPA1994c). Handrich summarizes data from testing at 21 boilers in Louisiana (Handrich 1999). D/F emissions range from less than 0.008 ng TEQ/dscm to as high as 0.88 ng TEQ/dscm for a unit equipped with a fabric filter. Finally, Gullett and others (in press) provide data from a firetube boiler where the boiler was intentionally operated under poor combustion conditions to assess the maximum potential for D/F formation. After a period of flame wall impingement and soot formation on the boiler tubes, combustion conditions were improved and D/F emissions increased to as high as 49 ng TEQ/dscm.

D/F emissions from boilers are expected to be dependent on boiler design, APCD type, particulate hold-up temperatures, combustion conditions, and feed composition. Table 4-1 summarizes control parameters associated with D/F and other organic emissions from boilers. Depending on the system configuration, demonstration of control parameters associated with D/F formation in boilers may coincide with both the DRE and SRE test conditions.

As explained in Section 4.2.1.3, boiler tubes may serve as particulate hold-up areas and lead to D/F

emissions. Because boilers typically have no rapid quench, the flue gas time and temperature window may be suitable for D/F formation. This premise is supported by data for incineration systems equipped with waste heat boilers or other types of heat exchangers, where D/F emissions ranging from about 1 to 40 ng TEQ/dscm have been measured (EPA 1999d). Heat exchanger exit temperature (measured at the exit of the last heat exchanger section) is considered a primary control parameter for D/F formation and control. Collection of D/F emissions data for boilers is recommended during conditions that achieve heat exchanger exit temperatures in the upper end of (but well within) the 400 to 750 °F range. For example, for a facility with heat exchanger exit temperatures ranging from 350 to 550 °F, D/F testing at the exit temperature of 550 °F would be preferred over testing at the exit temperature of 350 °F. Heat exchanger exit temperatures may fall in the upper end of the D/F formation window during either DRE or SRE conditions, depending on the facility-specific operating envelope. (Note: If the heat exchanger outlet temperature is maintained *above* the critical temperature range to prevent D/F formation, for example, above 800 °F, a *minimum* temperature limit may be appropriate instead. However, this situation is not expected to be likely, since the thermal recovery efficiency for the boiler would be compromised.) For boilers equipped with a dry APCD, the inlet temperature to the dry APCD is also considered a primary control parameter.

Demonstration of parameters related to combustion quality (see Section 4.2.2) can also be a consideration, especially for boilers that burn wastes resulting in combustion transients. Some boilers at chemical facilities burn different production run wastes in campaigns. These conditions should generally be evaluated by the permit writer prior to trial burn to determine the potential for transients. Demonstration of control parameters affecting combustion efficiency will most likely coincide with the DRE test condition.

Demonstrating key control parameters related to combustion quality may be problematic for some boilers based on potential test condition conflicts (Schofield and others 1997). For example, depending on the capacity of the forced draft fan, a facility burning a single high-Btu waste stream may be unable to add enough excess combustion air to demonstrate minimum combustion temperature and maximum feed rate simultaneously. Thus, two test conditions may be appropriate in some cases to demonstrate all of the key control parameters related to combustion.

Conducting D/F emissions testing during the DRE condition may not always be possible for reasons discussed in Section 4.2.2 (e.g., because simultaneous stack determinations for consolidated testing may

not be possible, or because the risk testing is being performed separately from performance testing). In these situations, it may be appropriate for a facility with predictable, homogeneous waste feeds and few combustion transients to conduct testing under normal combustion conditions (see Section 3.3.2.2). It is recommended that the facility still demonstrate heat exchanger exit temperatures (as well as inlet temperatures to a dry APCD device) in the upper end of the 400 to 750 EF range.

In summary, boilers with highly variable operations should generally collect D/F emission samples during DRE-like test conditions, as well as any other condition necessary to achieve heat exchanger exit temperatures (and inlet temperatures to a dry APCD device) in the upper end of the 400 to 750 EF window. This objective could result in multiple test conditions. Facilities with more predictable, homogeneous waste feeds and few combustion transients may opt to test only during the test condition achieving the requisite heat exchanger exit temperatures and APCD inlet temperatures, as appropriate (see Section 3.3.2.2).

Finally, EPA OSW recommends that normal soot blowing practices at a boiler generally be reflected during the D/F testing. Buekens and Huang summarize measurements showing that D/F emissions during soot-blowing can increase as much as 30-fold over normal operations (Buekens and Huang 1998). However, data for long operating periods are not available, and it is possible that more frequent cleaning of heat surfaces could lead to lower D/F formation overall on a long term basis (Buekens and Huang 1998). This guidance recommends that normal soot blowing procedures be determined from the facility's operating record and reflected during the D/F testing according to the methodology specified in *Technical Implementation Document for EPA's Boiler and Industrial Furnace Regulations* (EPA 1992b).   Prior to the test, soot blowing should generally not be performed on a more rapid cycle than normal.

4.5   D/F EMISSIONS FROM CEMENT KILNS

Cement kiln designs are described in detail in a report sponsored by the Portland cement kiln industry (Dellinger and others 1993). The majority of hazardous waste burning cement kilns utilize a long wet kiln design. A few hazardous waste burning kilns are long dry or preheater/precalciner dry units, and several facilities are beginning to replace long wet units with dry preheater/precalciner or semi-dry preheater/precalciner designs (Yonley 2000).

Cement kilns burn hazardous waste commercially (i.e., they accept waste from off-site generators) for use

as a fuel supplement in the production of Portland cement. Liquid wastes are typically injected into the hot end of the kiln. Solid wastes may be introduced into the calcining zone at some facilities. For long kilns, this means that the solid waste is introduced mid-kiln, and for preheater/precalciner kilns it is introduced onto the feed shelf. Containerized solid wastes may also be projected into the calcining zone by an air cannon mounted to the kiln hood. According to a technical support document to the hazardous waste combustor MACT rule (EPA 1999f), all cement kilns are equipped with either ESPs or fabric filters for particulate matter control. In some cases, the flue gases are cooled prior to the dry APCD. Add-on acid gas pollution control devices are not used at cement kilns, since the raw materials are highly alkaline and provide some degree of acid gas control.

D/F emissions data are available for most hazardous waste burning cement kilns. Test condition averages are highly variable, ranging from 0.004 to nearly 50 ng TEQ/dscm (EPA 1999d). The level of D/F emissions from a cement kiln may potentially be affected by a number of factors. However, the inlet temperature to the particulate matter control device is one factor that has been shown to consistently affect D/F formation (EPA 1999d).

Table 4-2 summarizes potential control parameters associated with D/F and other organic emissions from cement kilns. Data presented in numerous documents (Harris and others 1994; Lanier and others 1996; EPA 1999d and 1999e) demonstrate that D/F emissions from cement kilns increase exponentially with increases in inlet temperatures to the dry APCD within the D/F formation window (400 to 750 EF). A number of kilns have recently added flue gas quenching units upstream of the APCD to reduce inlet APCD temperature, and these additions have significantly reduced D/F emissions (EPA 1999d). This information suggests that maximum inlet temperature to the dry APCD system, as discussed previously in Section 4.2.1.3, is the primary control parameter related to D/F emissions for cement kilns. Collection of D/F emissions data should generally occur during a test condition that achieves maximum APCD inlet temperatures (for example, the SRE test condition, which is performed at a maximum APCD inlet temperature).

Parameters related to combustion quality (as described in Section 4.2.2) are generally less relevant for cement kilns than for incinerators and boilers. The operating envelope of cement kilns is dictated largely by the American Society for Testing and Materials specifications for their final product. Cement kilns operate

TABLE 4-2

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM CEMENT KILNS AND AGGREGATE KILNS

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS					
Post-Combustion Conditions: See Sections 4.2.1, 4.5 and 4.6	Maximum dry ESP inlet temperature (within the range of 400-750 EF)	SRE	Group A: 1 hour rolling average	Average of the test run averages	See Section 4.2.1.3
	Maximum fabric filter inlet temperature (within the range of 400-750 EF)				
	Aggregate Kilns: Maximum inlet temperature to extensive runs of ductwork (where cooling through the 400-750 EF temperature range occurs)				
Combustion Conditions: *(It is also recommended that these parameters be limited to control non-D/F organics, see Section 5.4)* See Sections 4.2.2, 4.2.6, 4.5 and 4.6	Batch feed conditions: - maximum batch waste feed rate at the location where the batch is fed - maximum carbon monoxide and/or total hydrocarbons	Any test where the post-combustion parameters identified in Section 4.2.1 are also demonstrated	Group A: 1 hour rolling average	Average of test run averages For carbon monoxide and/or total hydrocarbons, establish per applicable regulations	See Section 4.2.2.3.2 Test wastes with high volatility and oxygen demand. Other batch feed parameters that may be necessary to limit are listed in Section 4.2.2.3.2
	Aggregate Kilns: Consider Section 4.2.2.2 parameters on a case-by-case basis				

TABLE 4-2

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM CEMENT KILNS AND AGGREGATE KILNS (Continued)

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
PRIMARY CONTROL PARAMETERS (Continued)					
Feed Composition: See Sections 4.2.3, 4.5 and 4.6	Minimum sulfur-to-chlorine ratio at the stack (unless the S/Cl molar ratio during the test is well below 0.3)	Any test condition where a S/Cl ratio ≥ 0.3 is used	Group B: Feed stream analyses may be specified to monitor sulfur input	Average of the test run averages	See Sections 4.2.3.4, 4.5 and 4.6
	D/F contributions from dioxin-containing wastes	Any test with dioxin-containing wastes	Group B: Feed stream analyses may be specified to monitor dioxin input	Average of the test run averages	See Section 4.2.3.5
D/F Control Technologies: See Section 4.2.5	D/F-specific control technologies include carbon injection, carbon bed, catalytic oxidizers and D/F inhibitor technologies. If one of these control technologies is used to limit D/F emissions, permit limits on key control parameters as described in a technical support document to the hazardous waste combustor MACT rule (EPA 1999e) may be appropriate .				
SECONDARY CONTROL PARAMETERS					
Control of Precursors from Raw Material Organics: *(It is recommended that these parameters also be limited to control non-D/F organics, see Section 5.4)* See Sections 4.5 and 4.6	Maximum total hydrocarbons, as measured at both the main and bypass stacks, not to exceed regulatory limits	SRE	Group A: 1 hour rolling average	Establish per applicable regulations. Limits in addition to those specifically prescribed by regulation may be considered based on the results of the risk assessment.	Temporary total hydrocarbon monitors may be needed if the facility does not normally measure total hydrocarbons in both stacks.

TABLE 4-2

POTENTIAL CONTROL PARAMETERS ASSOCIATED WITH D/F EMISSIONS FROM CEMENT KILNS AND AGGREGATE KILNS (Continued)

	Control Parameter	Most Likely Achieved During	Parameter Type/Example Averaging Period*	How Limit May Be Established*	Other Considerations
TERTIARY CONTROL PARAMETERS					
Feed Composition: See Sections 4.2.3, 4.5 and 4.6	Total Chlorine D/F Inhibitors	These are not continuously monitored parameters, but pertain to selection of wastes and fuels for testing. Conditions for waste profile tracking may be specified by the permit writer.			Considerations are discussed in Sections 4.2.3, 4.5 and 4.6

Notes: D/F   =   dioxins and furans   ESP   =   electrostatic precipitator
            EPA   =   U.S. Environmental Protection Agency   SRE   =   system removal efficiency

         *   =   See Section 1.3.1 for a description of the Group A, B and C designations. Hourly rolling averaging periods are specified as examples, but other averaging periods and techniques may be considered. By establishing operating limits from the test as "the average of the test run averages," the permit writer can better ensure consistency between the manual emissions measurements and the permit. It is less desirable to establish an operating limit as "the average of the minimum (or maximum) hourly rolling averages from the three test runs," because the minimum or maximum operating extremes may only be demonstrated during a minor portion of the total stack sampling period.

at high temperatures (approaching 3,500 ºF) to achieve material temperatures of at least 2,700 EF, with typical gas residence times from 4 seconds to as high as 16 seconds. These conditions are conducive to highly efficient organic destruction. Although some cement kilns operate at elevated carbon monoxide levels, these levels are not necessarily indicative of poor combustion. A portion of the carbon monoxide in cement kilns is due to the calcination process. The calcination process releases large quantities of carbon dioxide, which can subsequently decompose into carbon monoxide at the extremely high temperatures in the kiln. In addition, carbon monoxide may be formed at the kiln exit where total hydrocarbons are volatilized from the raw materials and are partially oxidized.

Results from both kinetic modeling and field studies suggest that organics are efficiently destroyed when fed at the hot end of cement kilns (Dellinger and others 1993). DRE results seem to confirm this. DRE failures at cement kilns are extremely limited, and can generally be explained by high blank or baseline (non-hazardous waste) levels of POHCs. In one instance, DRE failure has been attributed to poor atomizer design (Dellinger and others 1993). However, facility-specific DRE testing should generally be sufficient to reveal design problems. For these reasons, Table 4-2 does not recommend control parameters related to combustion of liquid hazardous wastes introduced to the hot end of cement kilns.

Table 4-2 does recommend limiting combustion control parameters when kilns feed batch waste at mid- or feed-end locations. Batch wastes injected at mid- or feed-end locations may not experience the same elevated temperatures and long residence times as liquid wastes introduced at the hot end. In a worst-case scenario, volatile compounds may be released from the charge so rapidly that they are not able to mix with oxygen and ignite before they cool below a critical temperature, forming PICs (Dellinger and others 1993). Increased PICs, or precursor organics, may enhance formation of D/Fs. To ensure that D/F emissions are not under-estimated for the risk assessment, EPA OSW recommends that batch wastes be fed under simulated "worst-case" feeding conditions during the risk burn as discussed in Section 4.2.2.3.2. The recommended permit limits in Table 4-2 are also discussed in Section 4.2.2.3.2, together with a listing of other batch feed parameters that may be limited on a case-by-case basis, as necessary to protect human health and the environment. Some cement kilns self-restrict individual batch size to less than 1% of the total hourly fuel feed, and this practice may be considered in determining appropriate permit limitations.

In cement kilns, main stack emissions of total hydrocarbons are dominated by organics that are volatilized from the raw materials prior to entering the high temperature regions of the kiln (Schreiber and Strubberg 1994). The chlorination of these hydrocarbons is a potential source of D/F precursors, such as monochlorobenzene (Dellinger and others 1993). Bench-scale, as well as full-scale, tests by the industry have confirmed that hydrocarbons from raw materials play a significant role in governing the production of D/Fs (Sidhu and Dellinger 1997; Schreiber undated). In addition, D/Fs may actually be present in the raw materials and may volatilize once the raw materials reach sufficient temperatures, although the significance of these contributions to total D/F stack emissions is still under debate (EPA 1999d). Considering this information, EPA OSW recommends that D/F testing be performed at the upper end of the operating range for total hydrocarbons, as measured in both the main and bypass stacks, not to exceed applicable regulatory limits.

Although the operating conditions necessary for achieving high total hydrocarbon emissions may vary by facility, maximum total hydrocarbon levels are likely to be achieved by some combination of high production rate, high gas temperatures at the raw material feed end of the kiln, and low oxygen at the raw material feed end of the kiln. Dellinger observed an inverse relationship between total hydrocarbons and stack oxygen concentrations (Dellinger and others 1993), and Schreiber and Strubberg observed that raw-material-generated hydrocarbons decrease as kiln oxygen increases (Schreiber and Strubberg 1994). The organic content of the raw material can also significantly influence hydrocarbon levels. However, raw material characteristics are largely dictated by quarry location, and are not easily controlled for the purpose of testing. If total hydrocarbon levels increase substantially after the risk burn because of changes in raw materials, then re-testing may be necessary.

In the context of D/F and other organic testing, total hydrocarbon levels are recommended for use as a control parameter indicating levels of organics within raw materials that may be chlorinated from the hazardous waste fuel. In this case, total hydrocarbons are not being used strictly as an indicator of waste fuel combustion efficiency. EPA OSW recommends that site-specific risk assessments quantify risks from hazardous waste combustor emissions, regardless of source. Therefore, it may be appropriate for cement kilns that only monitor carbon monoxide, or that only monitor carbon monoxide or total hydrocarbons in a bypass stack, to install temporary total hydrocarbon monitors in the main and bypass stacks prior to and

during the D/F tests to ensure that total hydrocarbon emissions are being maximized. The need for permanent total hydrocarbon monitoring can be assessed by the permit writer after the risk assessment is completed and potential risks are evaluated.

Feed characteristics that can potentially influence D/F emissions are discussed in Section 4.2.3. The relevance to cement kilns is discussed here. Contradictory information exists regarding the significance of waste fuel chlorine. It has been proposed that the highly alkaline environment in a cement kiln scavenges available chlorine, making it unavailable for chlorination of organics. Data presented by Lanier from testing conducted at a full-scale facility showed 97% acid gas capture by the alkali material, and no effect on D/F emissions due to variations in chlorine feed rate (Lanier and others 1996). However, equilibrium calculations show lower chlorine capture at high temperatures and conversion of HCl to Cl_2, suggesting that even a highly basic chemical species such as calcium hydroxide would not always be expected to effectively control chlorinated hydrocarbon formation (including D/Fs) at temperatures above 400 EF (Dellinger and others 1993).   In addition, D/F emissions were reduced during full-scale testing at another facility where Na_2CO_3 was injected at the fuel end to react with chlorine, suggesting that fuel-based chlorine *can* affect D/F emissions in cement kilns (Schreiber and others 1995). Considering the uncertainty on this issue, a recommendation to maintain normal levels of chlorine during the risk burn is reasonable.

Metal catalysts in the waste, as discussed in Section 4.2.3.2, are not expected to be relevant to D/F testing at cement kilns. Spiking wastes with copper was not observed to affect D/F emission rates during full-scale testing of a cement kiln (Lanier and others 1996). Also, other metals that have been identified as D/F catalysts (iron and aluminum) are major ingredients in cement kiln raw materials.

D/F precursors, as discussed in Section 4.2.3.3, are expected to be dominated by precursors in the cement kiln raw materials, rather than precursors in the waste. However, if a facility burns wastes with significant quantities of D/F precursors, these wastes are recommended for use during D/F testing, rather than wastes without the precursors.

Naturally occurring D/F inhibitors, such as sulfur, are discussed in Section 4.2.3.4. Sulfur is expected to be present in the coal used for co-firing a cement kiln. During the D/F testing, EPA OSW recommends that coal not be fed at higher-than-normal rates, and low sulfur coal is preferred if a facility uses several coal

suppliers. Section 4.2.3.4 suggests that, if S/Cl molar feed ratios approach 0.3 or greater, waste and fossil fuel tracking conditions in the permit may be necessary after the risk burn to protect human health and the environment by ensuring that a minimum S/Cl ratio is maintained on an ongoing basis. In cement kilns, where the alkali raw materials provide some control of acid gases, the S/Cl molar ratio in the stack may be more relevant than the ratio in the feed. Other potential D/F inhibitors, such as calcium, may already be present in the raw materials.

In some cases, sulfur or other D/F inhibitors are intentionally added to a cement kiln to achieve D/F control. Schreiber has documented D/F emissions reductions after sulfur was added to the raw materials to increase the stack concentrations of SO_x from less than 20 ppm to above 300 ppm (Schreiber and others 1995). Schreiber also documented D/F emissions reductions when Na_2CO_3 was injected at the fuel feed end to react with chlorine in the system (Schreiber 1995). If sulfur or other D/F inhibitors are intentionally added to the system to achieve D/F control, then EPA OSW suggests that the recommendations in Section 4.2.5 for specific D/F control technologies should be followed.

There are currently no hazardous waste burning cement kilns utilizing carbon injection for D/F control. A special consideration for cement kilns is that injected carbon may interfere with the common practice of recycling cement kiln dust back into the production process. For a cement kiln to effectively utilize carbon injection, the carbon injection system may have to be installed after the APCD, along with a second APCD to collect the carbon. In addition, the use of carbon may increase total D/F synthesis when D/Fs in the cement kiln dust are accounted for, as explained in Section 4.2.5.

4.6   D/F EMISSIONS FROM AGGREGATE KILNS

Lightweight aggregate kiln design and operating practices are described in detail in a technical support document to the hazardous waste combustor MACT rule (EPA 1999f). Lightweight aggregate kilns typically burn only high-Btu, liquid fuel, and do not burn wastes at locations other than the hot end. Depending on the feed and system design, the temperature at the hot end of the kiln varies from 2,050 to 2,300 ºF, and combustion gas exit temperatures vary from 300 to 1,200 ºF (EPA 1999f). All hazardous waste burning lightweight aggregate kilns utilize fabric filters for particulate matter control (EPA 1999f).

D/F emissions data are available for only a few hazardous waste burning lightweight aggregate kilns. Test condition averages range from 0.04 to 2.9 ng TEQ/dscm (EPA 1999d). The data suggest that D/F emissions from lightweight aggregate kilns are influenced by more than APCD operating temperature, since all available D/F emissions data were generated at similar fabric filter inlet temperatures of around 400 EF. As explained in Section 4.2.1.3, D/F emissions from lightweight aggregate kilns appear to be primarily affected by the inlet temperature to extensive runs of un-insulated ductwork downstream of the kiln, where flue gas cools slowly through the 400 to 750 EF temperature range.

Table 4-2 summarizes potential control parameters associated with D/F and other organic emissions from lightweight aggregate kilns.   Dry particulate hold-up temperatures to extensive runs of ductwork and fabric filters are the primary control parameters related to D/F formation (see Section 4.2.1.3). Collection of D/F emissions data should generally occur during a test condition that achieves maximum ductwork inlet temperatures and APCD inlet temperatures (for example, the SRE test condition, which is performed at a maximum APCD inlet temperature).

Parameters related to combustion quality are discussed in Section 4.2.2. Demonstration of combustion parameters at lightweight aggregate kilns should generally be considered on a case-by-case basis. Lightweight aggregate kilns do not operate at combustion temperatures as high as those in cement kilns (see Section 4.5). However, the potential for poor combustion situations may be minimized, because aggregate kilns typically only burn high-Btu, liquid wastes in the flame zone. Historical operating data should generally be reviewed to determine whether a facility frequently experiences operating transients, as discussed in Section 4.2.2.3.1. If so, then the transient operations should generally be represented during the D/F testing. Permit limitations on the combustion parameters listed in Section 4.2.2.2 (or other parameters as appropriate) may be necessary to protect human health and the environment. However, if a facility maintains steady-state operations with very few fluctuations, demonstration of absolute minimum or maximum values for the Section 4.2.2.2 combustion parameters may be less critical.

As discussed in Section 4.5 for cement kilns, the raw materials which are fed to the cold end of aggregate kilns may contribute to elevated organic precursor concentrations which can affect D/F emissions. Therefore, D/F testing should generally be performed at the upper end of the operating range for total hydrocarbons. Since most aggregate kilns only monitor carbon monoxide, it may be appropriate to install

temporary total hydrocarbon monitors for the testing.

Feed composition is discussed in Section 4.2.3. Recommendations regarding feed characteristics that can potentially influence D/F emissions are similar to those discussed in Section 4.5 for cement kilns.

CHAPTER 5

ORGANIC EMISSIONS OTHER THAN DIOXINS AND FURANS

EPA OSW has recommended that human health and ecological risk assessments evaluate potential risks associated with organic emissions other than D/Fs, in addition to the risks from D/Fs (EPA 1998a and 1999b). The EPA OSW risk assessment guidance (EPA 1998a and 1999b) recommends that the final risk assessment clearly distinguish between the portion of stack emissions evaluated for risk, the portion considered to be non-toxic, and the portion that remains unknown. Therefore, the objective for the risk burn should be to characterize organic stack emissions as completely as possible. As stated in Chapter 2, it is recommended that the largest possible percentage of organic emissions be identified and quantified initially to minimize the need for re-testing, even though some compounds may eventually be eliminated from quantitative risk evaluation as part of the COPC selection process recommended in the EPA OSW risk assessment guidance (EPA 1998a).

This chapter addresses identification and quantification of organic emissions other than dioxins and furans. Stack determinations are discussed in Section 5.1. Key control parameters that EPA OSW recommends be demonstrated during the testing are identified in Section 5.2. All parameters may not be relevant for all systems, and the information in Section 5.2 should be considered in conjunction with the industry-specific information provided for incinerators and boilers in Section 5.3, and for cement kilns and lightweight aggregate kilns in Section 5.4, as well as facility-specific information.

5.1   STACK DETERMINATIONS FOR ORGANICS

EPA has conducted research to identify the types and quantities of organics emitted from hazardous waste combustion facilities (EPA 1998e; Ryan and others, 1996 and 1997; Midwest Research Institute and A.T.

Kearney 1997; Lemieux and others 1999). These research efforts indicate frequent detection of volatile and semivolatile organics including chloro-, bromo-, and mixed bromochloro-alkanes, alkenes, alkynes, aromatics, and polyaromatics, D/Fs, PAHs, PCBs, phthalates, nitrogenated and sulfonated organics, and short-chain alkanes (such as methane and propane). EPA reports frequent detection of chlorinated and brominated alkanes and alkenes (such as chlorinated ethenes), and suggests that chlorinated ethenes can serve as potential indicators of D/F formation (EPA 1998e). EPA supports ongoing research to improve the identification and quantification of organic emissions. However, uncertainty remains regarding the full suite of organic emissions from hazardous waste combustion facilities and the potential risks associated with those emissions.

Because organic emissions cannot be reliably predicted based on the feed, design, or operating practices at a particular facility, this guidance recommends that comprehensive organic emissions testing be performed to develop emissions data for site-specific risk assessments to accomplish the following three objectives:

C   Identification and quantification of specific toxic organic compounds (such as PAHs and PCBs) to assess their contribution to the total potential risk posed by the facility;

C   Identification and quantification of as many other constituents as possible, regardless of toxicity, to reduce uncertainty for the risk assessment;

C   Construction of an organics mass balance which estimates the completeness of the organic emissions characterization, to evaluate remaining uncertainty associated with the risk assessment.

The first objective can typically be achieved by sampling and analysis for specific compounds listed on volatile, semivolatile, and other target analyte lists. The second objective involves determinations for constituents that are not typically included on target analyte lists. Examples include tentatively identified compounds, as well as simple hydrocarbons. The third objective involves a measurement of Total Organic Emissions. Each of these objectives is discussed in more detail.

5.1.1   Target Analyte Lists

The first recommended objective of organics testing is to identify and quantify specific toxic organic compounds to assess their contribution to the total potential risk posed by the facility. Recommended target analyte lists for organics are provided in Appendix B of this document. Standard EPA methods (EPA 1996b) can be used to identify and quantify many organics that are potentially toxic, persistent, and bioaccumulative. For volatile and semivolatile organic compounds, SW-846 Methods 8260 and 8270 gas chromatography/mass spectrometry (GC/MS) procedures are preferred (EPA 1996b). The EPA methods, as written, are intended as guidance and are recommended as starting points for the development of standard operating procedures that will actually be used. Guidance on appropriate method modifications is provided in SW-846 (refer to Chapter 2 of SW-846 [EPA 1996b] and the applicable methods.) However, the facility should be able to demonstrate and document that the modified methods meet the DQOs for the particular application. Other methods not found in SW-846 may also be used if the user can demonstrate and document that the methods will generate data that meet the appropriate DQOs.

Stack determinations for PCBs are also recommended, based on evidence that PCBs can be emitted from combustion sources regardless of PCB contamination in the feed . An increasing body of information supports the likelihood that PCBs may be emitted as by-products of the combustion process. It is possible that PCBs are formed by the same reactions that produce D/Fs, discussed previously in Section 4.1. Lemieux hypothesized that, if PCBs and D/Fs are formed by similar mechanisms, then emissions of PCBs should correlate with emissions of D/Fs (Lemieux and others 1999). This hypothesis was tested by reviewing data where both PCBs and D/Fs were measured. An apparent trend was indeed found showing increased PCB emissions with increased D/F emissions. In most cases, PCBs were found in the stack even when there were no PCBs in the feed. Overall, PCB emissions exceeded D/F emissions by approximately a factor of 20, and this trend appeared to hold over five orders of magnitude in D/F emissions.

Alcock (Alcock and others 1999) and EPA (EPA 1997b) have established that waste combustion units contribute significantly to total emission inventories of PCBs. In addition, PCBs can be important from a risk standpoint. In the United Kingdom, where a TEQ is used to assess the potential toxicity of complex mixtures of D/Fs *and* PCBs, the PCBs contributed up to 60% of the TEQ for a cement kiln facility. For

other sources, the PCB contribution was more minimal.

The current toxicity approach for PCBs (EPA 1996c; Van den Berg and others 1998) calls for data on:

- C   Total PCB concentration; and

- C   Congener-specific analysis for the 12 toxic dioxin-like coplanar and mono-ortho-substituted PCBs listed in Table B.5-1.

The 12 dioxin-like PCBs are important because the rings can rotate into the same plane, similar to that of a D/F molecule. Studies have shown that these dioxin-like congeners can react with the aryl hydrocarbon receptor. This is the same reaction that is believed to initiate the adverse effects of D/Fs. The World Health Organization has derived interim toxicity equivalency factors (TEFs) for these coplanar PCBs (Van den Berg and others 1998). The TEFs are applied to congener-specific concentrations to evaluate dioxin-like toxicity. Risks from the dioxin-like congeners (evaluated using the slope factor for dioxins) are then added to risks from the rest of the mixture (evaluated using the slope factor for PCBs applied to total PCBs reduced by the amount of dioxin-like congeners). With proper planning, the PCB determination can be made using portions of the D/F sampling train extracts. More detail regarding sampling and analysis for PCBs is provided in Appendix B.

Finally, it may be appropriate for a facility to sample and analyze for additional constituents based on the types of wastes burned. For example, in addition to constituents on the volatile, semivolatile, and other target analyte lists, it may be appropriate for a facility to sample and analyze for compounds such as pesticides, nitroaromatics, and cyanides. It is recommended that stack determinations be considered for any highly toxic, persistent, or bioaccumulative constituent burned in significant quantities. Section 5.2.2 lists examples of historical waste feed information that can be reviewed to determine the significance of a particular constituent. Although the determination is somewhat subjective, a constituent may be appropriate to address as part of the stack sampling and analysis if it is prominent on several of the suggested rankings. Additional information on testing for facility-specific compounds is provided in Appendix B.

5.1.2 Tentatively Identified Compounds

The second recommended objective of organics testing is to identify and quantify as many non-target constituents as possible, regardless of toxicity. By identifying a larger portion of the unknown peaks in a chromatogram, a more complete organics mass balance can be achieved, and uncertainty in the risk assessment can be reduced.

In support of this second objective, a MS library search to identify non-target compounds is recommended, followed by review of the results by an experienced mass spectroscopist. Constituents identified based on the library search are referred to as tentatively identified compounds (TICs), since there is no reference standard analyzed at the same time as the unknown. The nearest internal standard is used for quantitation, and a relative response factor of one (1) is assumed. The resulting concentration is considered to be a semi-quantitative estimate, due to lack of a compound-specific response factor. Determinations for tentatively identified compounds are discussed further in Appendix B.

The EPA OSW risk assessment guidance (EPA 1998a) recommends that the semi-quantitative results for tentatively identified compounds be added into the "identified" portion of the stack emissions to ensure that appropriate credit is given to defensible efforts at identifying the maximum number of organic compounds. EPA OSW recommends that tentatively identified compounds that could significantly contribute to risk be considered for confirmation and quantification through the use of known standards.

5.1.3 Simple Hydrocarbons

Many organics lack EPA toxicity values, or they may not be toxic at all. These compounds are not typically included on standard target analyte lists. However, an important advantage of identifying, and quantifying as many organics as possible is the reduction of uncertainty for the risk assessment. Methane and other aliphatics can comprise a significant percentage of total stack organics, and specific determinations for methane, propane, and other short-chain aliphatics can potentially alleviate concerns about the percentage of the total organic mass that might be toxic.

One simple way to quantify non-toxic volatile hydrocarbons without expanding the sampling effort is to utilize information already available as part of the Total Organic Emissions determination (discussed in Section 5.1.4). The Total Organic Emissions determination involves measurement of volatiles by field gas chromatography, and an initial calibration is performed using methane, ethane, propane, butane, pentane, hexane and heptane. If sample analysis shows that a stack gas constituent has the same retention time as one or more of the calibration standards, then that constituent can be quantified and included in the "identified" portion of the stack emissions. A facility may also prefer to calibrate the field gas chromatograph with additional compounds to identify more volatile hydrocarbons, thereby moving those compounds from the "unknown" to the "identified" portion of the organic stack emissions. Analysis for simple hydrocarbons is discussed further in Appendix B.

5.1.4   Total Organic Emissions

Unfortunately, only a limited number of organic compounds can be accurately identified and quantified using standard stack gas sampling and analysis methods. A portion of the emissions profile remains unaccounted for. The third recommended objective of organics testing is construction of an organics mass balance to qualify the completeness of the organic emissions characterization. This information is used to evaluate remaining uncertainty associated with the risk assessment. This third objective involves a measurement of Total Organic Emissions.

The Total Organic Emissions determination (EPA 1996d) measures organic fractions for three boiling point ranges: 1) a volatile field gas chromatography (FGC) fraction (boiling points less than 100 EC); 2) the semivolatile, total chromatographable organics (TCO) fraction (boiling points between 100 and 300 EC); and 3) the non-volatile, gravimetric (GRAV) fraction (boiling points greater than 300 EC). The sum of the concentrations for the three fractions represents total organic mass. The procedure is discussed further in Appendix B.

EPA OSW recommends the procedure described in Appendix B as the best currently available way to cost effectively determine total recoverable organic mass and characterize uncertainty in the risk assessment. Permit writers should generally consider updated or expanded techniques if and when they become

available.

EPA OSW has recommended that the final result from the Total Organic Emissions determination be used to compute a total organic emissions (TOE) factor, defined as total organic emissions divided by the sum of the identified organics (EPA 1998a). The TOE factor is typically presented in the uncertainty section of the risk assessment report to clearly qualify how much of the stack emissions have been evaluated for risk. Permitting authorities can evaluate the TOE factor and assess to what extent actual risks may be greater than estimated risks (EPA 1998a). TOE factors ranging from 2 to 40 have been computed (EPA 1998a). Lower TOE factors can be achieved by more complete characterization of stack emissions (i.e., more "identified" compounds in the denominator), and facilities should consider this in determining appropriate stack measurements for the risk burn (Sections 5.1.1 through 5.1.3).

The importance of the Total Organic Emissions determination for site-specific risk assessments cannot be over-emphasized. Studies (EPA 1976; Pellizzari and others 1980) have shown that analyses based strictly on target analyte lists may account for less than 20% of the total organic material in an emission sample. Without a Total Organic Emissions determination, a final risk assessment report cannot explain how much of the total stack emissions have been evaluated for risk, significantly complicating the risk management decision.

5.2   CONTROL PARAMETERS TO BE CONSIDERED FOR RISK BURNS

This section identifies key control parameters that are expected to affect organic emissions, and that EPA OSW recommends be considered in establishing the risk burn test conditions. Depending on site-specific considerations, these control parameters may need to be limited in the RCRA permit after the risk burn to protect human health and the environment by ensuring that organic emissions remain within the measured levels on an ongoing basis.

Most of the control parameters listed in this section pertain to combustion conditions that have already been discussed in Section 4.2.2. Information from Section 4.2.2 is referenced, as appropriate, instead of repeating the information here.

Several of the control parameters identified in this section may currently be limited in association with the DRE standard, or will soon be limited pursuant to the requirements of the hazardous waste combustor MACT rule. To the extent that risks from non-D/F organics are already adequately controlled by regulatory limits on key control parameters, then fewer risk-based limits may be needed in the RCRA permit. However, if regulatory controls are not applicable or sufficiently comprehensive, then additional risk-based limits may be necessary to protect human health and the environment. A greater number of risk-based permit limitations may be necessary when the risk burn and RCRA or MACT performance tests reflect different operating modes.

Recommended control parameters that are expected to affect organic emissions are categorized according to combustion conditions (Section 5.2.1) and feed composition (Section 5.2.2). All parameters may not be relevant for all systems, and the information in Section 5.2 should be considered in conjunction with the industry-specific information provided for incinerators and boilers in Section 5.3, and for cement kilns and lightweight aggregate kilns in Section 5.4, as well as facility-specific information. The discussions and recommendations in this section are based on the underlying assumption that all hazardous waste combustors are required by RCRA or MACT regulation to operate under combustion conditions that meet or exceed 99.99 percent DRE.

5.2.1 Combustion Conditions

Recommendation -- EPA OSW recommends that, whenever possible, facilities perform testing for non-D/F organics during the DRE test conditions and that the challenging combustion scenarios discussed in Section 4.2.2.3 be represented during the testing (if applicable to a particular system). The challenging combustion situations described in Section 4.2.2.3 include: 1) transient conditions; 2) operation with containerized or batch waste feeds; and 3) high carbon monoxide situations.

Combustion parameters identified in Section 4.2.2.2 should automatically be addressed when organics testing is performed during the DRE test conditions, since these parameters are typically demonstrated and limited as part of the DRE determination. The combustion

parameters listed in Section 4.2.2.2 include: 1) minimum primary and secondary combustion chamber exit temperatures; 2) maximum combustion gas velocity; 3) maximum waste feed rate at each feed location; 4) limitations on waste feed composition and batch feeds; and 5) maximum flue gas carbon monoxide and/or total hydrocarbon concentrations.

The recommendation for organics sampling during the DRE test is a general guideline. Some facilities and permit writers may be faced with situations where this general guideline is not appropriate. For example, DRE testing may already have been conducted in advance of the risk burn, or the use of surrogate waste for the DRE test might conflict with the objective to use actual wastes during the non-D/F organic testing. These and other situations call for decisions regarding the specific combustion conditions to be demonstrated. Therefore, this guidance recommends that the challenging combustion scenarios described in Section 4.2.2.3 (if applicable) be preferentially targeted for organics testing. As appropriate, it is recommended that permit limits for the Section 4.2.2.2 combustion parameters be established based on organics testing conducted under these challenging combustion scenarios. In addition, a facility-specific review of trial burn and historical operating data should generally be performed to determine whether the challenging combustion scenarios correlate with other operating or feed parameters. If so, it is recommended that the correlating parameters be demonstrated during the testing and limited in the permit as necessary to protect human health and the environment in addition to, or possibly in lieu of, the combustion parameters listed in Section 4.2.2.2. Caution should be exercised to ensure that targets during the organics testing for the Section 4.2.2.2 combustion parameters are not substantially different from those demonstrated during the DRE test.

Finally, it is important to recognize that some combustion units operate under extremely steady-state conditions, at temperatures and residence times that should routinely ensure good combustion. Challenging combustion situations, such as those described in Section 4.2.2.3, do not occur. Combustion conditions may not fluctuate at all, and carbon monoxide may be near zero. Ideally, logistics will favor combining the organics testing with the DRE test. If so, then the combustion parameters listed in Section 4.2.2.2 should automatically be addressed, since

they are typically demonstrated and limited as part of the DRE determination. However, if
combined testing is not possible, then consideration may be given to testing under normal
combustion conditions, as appropriate (see Section 3.3.2.2). Historical operating data for the
appropriate combustion parameters should generally be reviewed to verify that the facility
maintains steady-state operations with very few fluctuations. Demonstration of absolute
maximum or minimum values for the combustion parameters listed in Section 4.2.2.2 during
organics testing may be less critical for steady-state operations. In lieu of specific permit limits
for the parameters listed in Section 4.2.2.2, periodic reporting to confirm continued absence of
transients may be appropriate. When organics testing cannot be performed in conjunction with
the DRE test, caution should be exercised to ensure that targets during the organics testing for
the combustion parameters listed in Section 4.2.2.2 are not substantially different from the levels
demonstrated during the DRE test.

For most incineration and boiler systems, the generation of organic products of incomplete combustion is typically associated with poor combustion situations (organic emissions from cement kilns and lightweight aggregate kilns are typically dominated by organics that are volatilized from the raw materials, but this is discussed later in Section 5.4). Berger has documented the effects of inefficient burner operation and oxygen control (Berger and others 1996). These conditions led to incomplete combustion and subsequent increases in fly ash and carbon monoxide and total hydrocarbon concentrations. Linak has documented PCC exit total hydrocarbon levels in excess of 10,000 ppm during very intense transient puffs arising from batch feed operations at a pilot-scale unit, and has performed chemical analysis to show that the puffs can contain numerous hazardous compounds, even though adequate DREs (>99.99%) may be achieved (Linak and others 1987). Historically, levels of oxygen, carbon monoxide, and total hydrocarbons have been used as surrogate indicators of good combustion to minimize PIC emissions.

Examples of operating conditions that may lead to increased PIC formation include:

- C Insufficient temperatures in either the PCC or SCC, leading to incomplete combustion.

- C Excess flue gas velocity or flow leading to shorter residence times in the combustion unit and incomplete combustion;

- C Batch-fed containers with high oxygen demand that can lead to transient, low oxygen

conditions and incomplete combustion;

C   Feeding of low-Btu solids or aqueous liquids that can reduce combustion temperatures.

These situations are typically addressed during performance testing under DRE conditions. To the extent possible, DRE tests are conducted at minimum combustion temperatures in the PCC and SCC, maximum flue gas velocity or flow, and maximum feed rate of each waste type (EPA 1989 and 1992b). Therefore, a successful DRE test should generally result in the maximum organic PIC emissions for incinerators and boilers. In addition, the challenging combustion scenarios discussed in Section 4.2.2.3 should generally be represented during the testing if they are applicable to a particular system. The challenging combustion situations described in Section 4.2.2.3 include: 1) transient conditions; 2) operation with containerized or batch feeds; and 3) high carbon monoxide situations.

The combustion parameters which should generally be emphasized for organic emission testing are the same as those identified in Section 4.2.2.2. These parameters include:

C   Minimum PCC and SCC combustion temperatures;

C   Maximum combustion gas velocity as an indicator of residence time;

C   Maximum waste feed rate for each feed location;

C   Limitations on waste feed composition and batch/containerized feeds;

C   Maximum flue gas carbon monoxide and/or total hydrocarbon concentrations.

These parameters are usually demonstrated in conjunction with the DRE test condition. However, there may be situations where it may not be possible to perform non-D/F organic emissions testing during the DRE test. For example, the use of surrogate waste for the DRE test might conflict with the objective to use actual wastes during the non-D/F organic testing. In these situations, EPA OSW recommends that the challenging combustion scenarios described in Section 4.2.2.3 be preferentially targeted for organics testing (if applicable) because of increased potential for localized oxygen deficiencies and carbon monoxide/total hydrocarbon spikes. As necessary to protect human health and the environment, permit limits for the Section 4.2.2.2 combustion parameters should be established based on organics testing conducted under

these challenging combustion scenarios. In addition, a facility-specific review of trial burn and historical operating data should generally be performed to determine whether the challenging combustion scenarios correlate with other operating or feed parameters. If so, it is recommended that the correlating parameters be demonstrated during the testing and limited in the permit as necessary to protect human health and the environment in addition to, or possibly in lieu of, the combustion parameters listed in Section 4.2.2.2.

At some facilities, the challenging combustion scenarios identified in Section 4.2.2.3 may not occur. For steady-state systems, demonstration of absolute minimum or maximum values for the Section 4.2.2.2 combustion parameters during organics testing may be less critical. Although demonstration of these control parameters can ideally be accomplished by combining the organics testing with the DRE demonstration (which is preferred whenever possible), consideration may be given for some steady-state systems to performing the organics testing under normal conditions. As discussed in Section 3.3.2.2, testing at normal conditions may be appropriate where the facility can establish a monitoring plan and permit conditions can be developed as necessary to protect human health and the environment to ensure that the test conditions are representative of long-term operations. A permit writer generally should consider the extent to which normal conditions represent potential emissions and risks over the permitted operating range in determining whether testing at normal conditions is appropriate. If organic emissions data are collected under normal conditions, caution should be exercised with respect to operating parameters where the average value is significantly different than operating extremes.

5.2.2 Feed Composition

> **Recommendation --** *EPA OSW recommends that, whenever possible, actual wastes (rather than surrogate wastes synthesized from pure compounds) be burned during the non-D/F organics testing, and that representative, but challenging, feeds be selected for the test. High quantity, routine and recurring waste streams are generally preferred, with special emphasis on wastes that may cause combustion transients (Section 4.2.2.3.1) and wastes containing highly toxic, persistent and bioaccumulative constituents.*

Waste selection for non-D/F organic testing can be very important, because the types of organic PICs may

relate directly to the chemical composition of the waste. EPA OSW recommends that actual wastes, and not surrogate wastes synthesized from pure compounds, be used whenever possible. The goal for the risk burn is to choose representative, but challenging, feeds: actual wastes which may cause elevated or more highly toxic emissions are preferred for the test.

When choosing actual wastes, EPA OSW recommends that the focus be on high quantity, routine, and recurring waste streams, with special emphasis on wastes that may cause combustion transients (Section 4.2.2.3.1) and wastes containing highly toxic, persistent, or bioaccumulative constituents. Examples of historical information that can assist in a review of actual wastes include the following:

- C   A listing of the top percentage (e.g., top 75 percent) waste receipts by quantity for a given period with descriptions of:

    -        source or process generating the waste;
    -        annual weight treated;
    -        hazardous waste code(s);
    -        physical description;
    -        chemical description;
    -        feed mechanism and feed location to the combustion unit.

- C   A ranking by weight of the top percentage of chemical constituents treated over a given period.

- C   A ranking which identifies wastes containing constituents with the highest toxicity, persistence, and bioaccumulation potential.

- C   A summary of minimum, maximum, and average values for the wastes fed via each feed mechanism into the combustion unit over a given period for:

    -        heating value;
    -        percentage total chlorine;
    -        percent ash;
    -        percent water;
    -        percent solids;
    -        viscosity (as appropriate).

- C   If historical operating data indicates that the facility experiences routine transients, a summary of the waste streams or waste characteristics which appear to correspond to the transient operations.

EPA OSW recommends that candidate wastes for organic emissions testing be identified considering the ability of the waste to achieve the desired combustion conditions (i.e., tax the combustion unit), the ability of the waste to represent toxic, persistent, and bioaccumulative compounds, and predicted availability of sufficient quantities of the waste streams to complete the relevant portions of the risk burn. Efforts generally should be made to schedule the testing for a time period when the target wastes will be available. However, it may be appropriate to review and evaluate waste selection a few weeks prior to the test based on actual waste stockpiles or scheduled waste receipts.

If a facility burns a large number of small waste streams, or if large quantities of uniform wastes are not available, then the inventory of actual wastes might be insufficient for completing the non-D/F organics emissions testing. A combination of real waste and synthetic waste (or spiked actual wastes) should generally be used in this situation. To the extent possible, simulated wastes should represent the high quantity, routine actual waste streams at a facility, while also achieving the goals outlined in this section. For example, simulated wastes should generally be physically and chemically configured to challenge the combustion unit. Key characteristics from Section 4.2.2.3.1 include physical form, viscosity, moisture, heating value, chlorine, volatility and oxygen demand. It may also be appropriate to spike the simulated wastes to be chemically similar to actual wastes in terms of highly toxic, persistent, or bioaccumulative constituents. In certain circumstances (e.g., to represent a significant waste stream that is not yet being generated, or to represent mixed hazardous/radioactive wastes which present special sampling and analytical challenges), it may be appropriate to use 100 percent surrogate wastes. In the case of batch or containerized wastes, it will generally be more important to focus on maximizing the amount of volatile material within each container, as discussed in Section 4.2.2.3.2, than to use a real waste with less oxygen demand.

Finally, the facility should generally provide protocols for monitoring and tracking waste stream information on an ongoing basis. The protocols should generally identify methods and procedures for comparing future waste characteristics to the wastes burned during the organic emissions testing. This information may be used to define the permitted variation in waste stream composition after the test, or to determine the need for retesting. Parameters of interest are generally expected to closely mirror those reviewed to plan the test in the first place.

5.3   ORGANIC EMISSIONS FROM INCINERATORS AND BOILERS

Hazardous waste incineration and boiler systems are described briefly in Sections 4.3 and 4.4. Non-D/F organic emissions from incinerators and boilers are likely to be dependent on both combustion conditions and feed composition. In summary, all of the considerations discussed in Section 5.2 are also appropriate to consider with respect to incinerators and boilers. Key control parameters are summarized in Table 4-1.

As discussed in Section 4.4, demonstrating key control parameters related to combustion quality may be problematic for some boilers. For boilers, conflicting parameters of maximum waste feed rate and minimum combustion temperature are very prevalent, especially for those boilers with varying production loads for steam generation. Minimum combustion temperature will occur at minimum loads (and therefore at lower fuel feed rates). Maximum waste feed rate will normally occur at maximum production load (maximum steam generation) at a temperature higher than the minimum. Thus, two test conditions may be appropriate in some cases to demonstrate all of the key control parameters related to combustion.

5.4   ORGANIC EMISSIONS FROM CEMENT KILNS AND LIGHTWEIGHT AGGREGATE KILNS

Cement kiln and lightweight aggregate kiln systems are described briefly in Sections 4.5 and 4.6. As discussed in Section 4.5, parameters related to combustion quality are generally less relevant for cement kilns and lightweight aggregate kilns than for incinerators and boilers. However, naturally occurring organics are driven out of the raw materials at the cold end of the kiln.

Control parameters associated with organic emissions from cement kilns are identified in Table 4-2. Conditions relative to combustion quality are generally limited to situations where batch or containerized wastes are fed. Batch wastes injected at mid- or feed-end locations may not experience the same elevated temperatures and long residence times as liquid wastes introduced at the hot end. The remaining recommendations in Section 5.2.1 regarding combustion conditions are not typically relevant to cement kilns.

Since organic emissions from cement kilns are likely to be dominated by organics volatilized from the raw

materials, the recommended focus during the risk burn is to maximize total hydrocarbon emissions in the main and bypass stacks, not to exceed applicable regulatory limits. Although the operating conditions necessary for achieving high total hydrocarbon emissions may vary by facility, maximum total hydrocarbon levels are likely to be achieved by some combination of high production rate, high gas temperatures at the raw material feed end of the kiln, and low oxygen at the raw material feed end of the kiln. These conditions are most likely to be achieved during a high temperature or SRE test. The recommendation to maximize total hydrocarbon emissions is discussed further in Section 4.5.

Control parameters associated with organic emissions from lightweight aggregate kilns are identified in Table 4-2. For lightweight aggregate kilns, EPA OSW recommends that demonstration of combustion parameters be considered on a case-by-case basis. Lightweight aggregate kilns do not operate at combustion temperatures as high as those in cement kilns. However, the potential for poor combustion situations may be minimized, because aggregate kilns typically only burn high-Btu, liquid wastes in the flame zone. Historical operating data should generally be reviewed to determine whether a facility frequently experiences operating transients, as discussed in Section 4.2.2.3.1. If so, it is recommended that the transient operations be represented during the organic emissions testing and permit limitations on the combustion parameters listed in Section 4.2.2.2 (or other parameters as appropriate) may be necessary to protect human health and the environment. However, if a facility maintains steady-state operations with very few fluctuations, demonstration of absolute minimum or maximum values for the Section 4.2.2.2 combustion parameters may be less critical. As discussed for cement kilns, raw materials may contribute to elevated organic emissions at lightweight aggregate kilns, and it is recommended that organics testing be performed at the upper end of the operating range for total hydrocarbons.

The recommendations in Section 5.2.2 regarding feed composition are generally appropriate for cement kilns and lightweight aggregate kilns. Although organic emissions may be influenced more by the raw materials than the waste feeds, it is reasonable to expect that representative, actual wastes should be burned for the risk burn. Selection of liquid wastes burned at the hot end of a cement kiln or aggregate kiln is expected to be less complex than for incinerators and boilers, because wastes are blended to meet fuel specifications. However, the waste characterization information discussed in Section 5.2.2 generally should be provided for the as-blended fuel to the extent possible, as well as for wastes fed at locations other

than the hot end of the kiln. For blended fuel, it may not be possible to perform a characterization by top percentage of waste receipts. In this case, EPA OSW recommends that an alternate ranking scheme be developed to reflect the chemical and physical characteristics of the blended fuel.

CHAPTER 6

METAL EMISSIONS

EPA OSW has recommended that metal emissions be evaluated in site-specific risk assessments because they can pose potential human and ecological risks (EPA 1998a and 1999b). Since most facilities are either controlling metals emissions or will soon control metals emissions pursuant to the requirements of the hazardous waste combustor MACT rule, the primary consideration for the risk burn is whether additional control beyond applicable regulatory standards may be warranted at a particular site (see also Sections 1.3.2 and 1.3.3). This chapter reviews emissions and operating data that may need to be gathered during the risk burn to assist in this determination.

Metal emissions from hazardous waste combustors are highly dependent on metal volatility, metal feed rates, and air pollution control efficiency. Section 6.1 provides information on metals volatility. Section 6.2 reviews specific feed and APCD control parameters that can influence metal emissions, with emphasis on the control parameters identified in the hazardous waste combustor MACT rule.   Section 6.3 discusses additional risk-based emissions and feed rate limitations which may need to be considered on a site-specific basis. Finally, Section 6.4 discusses metals speciation. Although recommended speciation assumptions for combustion risk assessments are provided in the EPA OSW risk assessment guidance (EPA 1998a), additional emissions data may need to be collected during the risk burn if a facility wishes to utilize site-specific information.

6.1   METAL VOLATILITY GROUPINGS

Metals can be grouped as volatile, semivolatile, or low-volatile. The distinctions between the three volatility groupings are not absolute, since metals behavior can vary for different combustion systems. However, volatility is a fundamental indicator of metals behavior and control in hazardous waste combustion systems, and the volatility groupings establish a general framework regarding metals behavior.

This section reviews the general characteristics of each volatility group and graphically depicts the relative volatility of the eighteen potentially toxic metals identified in Section 2.3. The discussion in this section is intended to be a general discussion encompassing all of the metals that may be addressed in a risk assessment. For six metals specifically regulated under the MACT rule, volatility groupings are defined by regulation, and the MACT rule volatility designations are reviewed later in Section 6.2.

Volatile metals are defined by EPA as metals that have high vapor pressures (and are typically in vapor form) in the combustion chamber as well as in the cooler downstream APCD components of the combustion system (EPA 1997e). Emissions of volatile metals are highly dependent on feed rate and the use of air pollution control techniques involving adsorption or absorption (e.g., carbon technologies and wet scrubbers). Volatile metals are not controlled by air pollution control technologies designed for removal of particulate matter, such as fabric filters or electrostatic precipitators. (EPA 1996a, 1997e, 1999d, and 1999e).

The theoretical relationship between metal feed rate and emissions for volatile metals, assuming that all other variables are held constant, is depicted in Figure 6-1 (EPA 1997e). Volatile metals are dominated by the regime designated as "Region A" on Figure 6-1, where the metal completely vaporizes in the combustion chamber and remains in a vapor form throughout the entire system, including the cooler APCD components. Conversely, Region A is relatively small or non-existent for semivolatile and low-volatile metals, due to their very low vapor pressures at APCD temperatures.

Semivolatile metals typically have higher vapor pressures at combustion temperatures and lower vapor pressures at APCD temperatures (EPA 1997e), leading to vaporization in the combustion chamber, followed by condensation onto particulates (often of less than a 1-micron diameter) before entering the APCD (EPA 1996a, 1997e and 1999d). Emissions of semivolatile metals are a function of both feed rate and APCD removal efficiency for fine, submicron particulate matter (EPA 1996a, 1997e and 1999d).
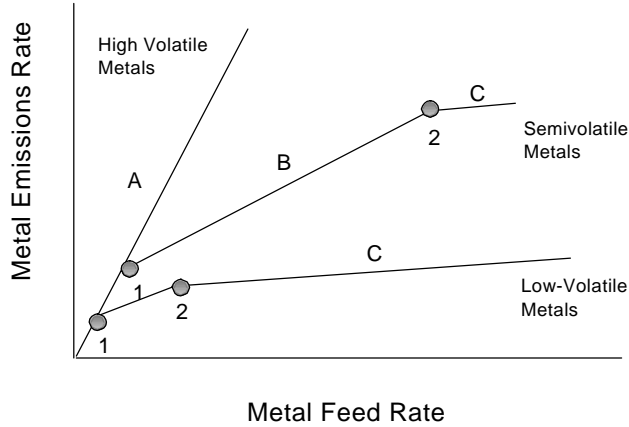
Figure 6-1 depicts the theoretical relationship between metal feed rate and emissions for semivolatile metals, assuming that all other variables are held constant (EPA 1997e). Semivolatile metals are dominated by the regime designated as "Region B" on Figure 6-1. As the feed rate of a metal increases, the

FIGURE 6-1

METAL VOLATILITY REGIMES

A - Metal in vapor phase
B - Metal condensed on fine particulate
C - Metal entrained as larger particulate

1 - Saturated vapor at
      APCD temperature
2 - Saturated vapor at
      combustion temperature

Reproduced from EPA (1997e)

metal vapor at the APCD temperature becomes saturated (Point 1). In Region B, the metal begins to condense at the APCD temperatures, primarily onto fine particulate matter. The slope of the line in Region B is determined by the APCD removal efficiency for fine particulate matter.

Low-volatile metals vaporize to a lesser extent at combustion temperatures and partition to a greater extent to bottom ash, other residue, cement kiln clinker, or entrained particulate matter in the flue gas (EPA 1996a, 1997e and 1999d). Low-volatile metal emissions are more strongly related to the operation of the APCD than to feed rate. Evaluations conducted by Springsteen (Springsteen and others 1997) and EPA

(EPA 1997e) indicate that there is a stronger relationship between emissions and feed rate for volatile and semivolatile metals than for low-volatile metals. For low-volatile metals, SREs tend to increase strongly with increasing feed rate (i.e., emissions increases are not generally proportional to feed rate increases).

The theoretical relationship between metal feed rate and emissions for low-volatile metals, assuming that all other variables are held constant, is depicted in Figure 6-1 (EPA 1997e). Low-volatile metals are dominated by the regime designated as "Region C" on Figure 6-1 because of their low vapor pressures, even at high combustion temperatures. As the feed rate of a metal increases, the metal vapor at the combustion temperature becomes saturated (Point 2). Additional metals fed beyond this rate remain as solids in the combustion chamber. Metal emissions continue to increase somewhat with increased feed rate in Region C, due to increased concentrations of metals in the entrained fly ash. However, emissions do not increase as rapidly as in Region B because no more metals vaporize, and metals entrained as larger particulate are captured in the APCD more efficiently than metals condensed onto submicron particulate matter.

Figure 6-2, reproduced from *Trace Elements - Emissions from Coal Combustion and Gasification* (Clark and Sloss 1992), graphically depicts the relative volatility for sixteen of the potentially toxic metals discussed in Section 2.3. Group 1 represents the low-volatile metals, Group 2 represents the semivolatile metals, and Group 3 represents the volatile metals. The overlapping circles indicate that partitioning behavior can vary for different combustion systems with different operating conditions.

Aluminum and silver were not categorized by Clark and Sloss. However, based on vapor pressure data for aluminum and on information found in a report sponsored by the Portland cement kiln industry (Dellinger and others 1993), aluminum would be expected to exhibit low-volatile behavior as an oxide. As a chloride, aluminum could be semivolatile to volatile. Silver would likely be classified as a low-volatile metal, based on the species expected to be formed within combustion environments.

It is important to note that distinctions between volatile, semivolatile, and low-volatile metals can vary among studies, test conditions, and type of facility (Springsteen and others 1997; Clark and Sloss 1992). Moreover, metal emissions are affected by design differences in combustion units (such as differences

FIGURE 6-2

METAL VOLATILITY GROUPS

Group 3

Hg

Se

Group 2

As Cd Pb
Sb Tl Zn

Ba Be Co Cr
Cu Ni V

Group 1

Mn
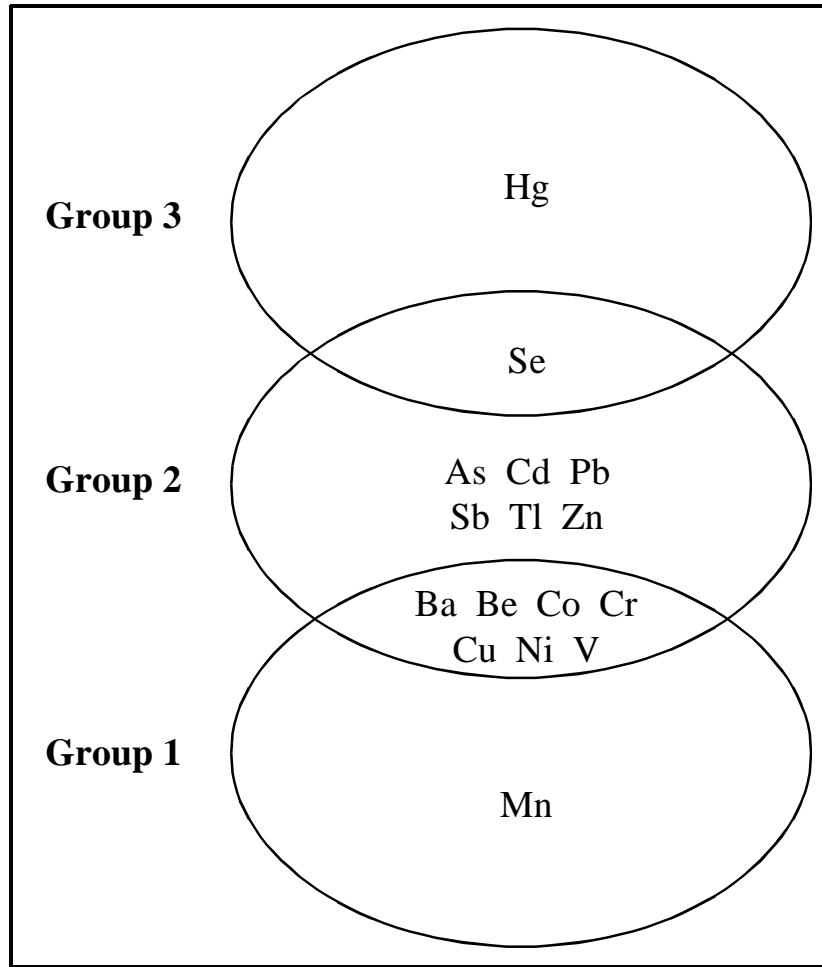
Reproduced from Clark and Sloss (1992)

among kilns, liquid injection, and controlled air designs), combustion stoichiometry and flue gas flow rates (higher gas velocities can lead to higher particle/metal entrainment), operating temperatures (metal volatility typically increases with increasing temperature), the physical form and species of the metal, the presence of mineral species which may preferentially bind with metals (these may be contained in the raw materials in cement kilns and lightweight aggregate kilns), the presence of chlorine (which generally increases metal volatility), and APCD removal efficiency (Energy and Environmental Research Corporation [EER] 1991; Cesmebasi and others 1991; Springsteen and others 1997; Linak and Wendt 1998). The figure reproduced from Clark and Sloss may not fully represent the behavior of certain metals in certain systems. For example, Springsteen found that the metals antimony and arsenic exhibit low-volatile behavior in cement kilns (probably due to their affinity for the cement matrix) (Springsteen and others 1997).

Control parameters for volatile, semivolatile, and low-volatile metals and their expected behavior in incinerators, boilers, cement kilns, and lightweight aggregate kilns are discussed further in the following section.

6.2   MACT CONTROL PARAMETERS FOR METALS

The metals emission standards which apply to hazardous waste combustors vary considerably, depending on the type of combustion device and the time frame being considered. For hazardous waste burning boilers and industrial furnaces, metals emissions have been regulated since 1991 under the BIF rule (40 CFR Part 266 Subpart H). The BIF standards are risk-based standards, but only consider exposures via the inhalation exposure pathway, as explained previously in Section 1.3.1. BIF control parameters are discussed in *Technical Implementation Document for EPA's Boiler and Industrial Furnace Regulations* (EPA 1992b). Similar provisions have been applied at some hazardous waste incineration facilities through individual permit decisions, pursuant to the omnibus authority of Section 3005(c)(3) of RCRA, as codified at 40 CFR 270.32(b)(2). More recently, technology-based MACT metals emission limits have been promulgated for hazardous waste burning incinerators, cement kilns, and lightweight aggregate kilns (EPA 1999c). Facilities have three years from the MACT rule promulgation date (September 30, 1999) to comply with the revised standards. Upon documentation of compliance with MACT, the BIF metal

emissions standards are superseded (however, any RCRA permit requirements or conditions related to the combustor remain in effect until that permit is either modified to remove the conditions or the permit is terminated or expires). Technology-based standards for hazardous waste burning boilers are anticipated in a future MACT rulemaking.

This section reviews the key control parameters influencing metal emissions, with emphasis on the control parameters identified in the hazardous waste combustor MACT rule. The MACT control parameters for metals are similar to BIF control parameters. However, the MACT parameters have been reviewed more recently against an extensive metals emissions database.

The purpose of reviewing MACT control parameters is not to suggest that MACT emissions standards should necessarily be imposed within the context of risk-based permitting, or to imply that any facility will be required to achieve early compliance with MACT emissions standards. Rather, the purpose of reviewing the MACT control parameters in this guidance is to identify the feed and operating conditions that influence metals emissions, as well as to highlight the controls which will be implemented at most hazardous waste combustors in accordance with the requirements of the MACT rule. To the extent that risks from metals are already adequately controlled by regulatory limits on key control parameters, then fewer site-specific risk-based limits may be needed in the RCRA permit. However, if regulatory controls are not applicable or sufficiently comprehensive, then additional site-specific risk-based limits may be necessary to ensure protection of human health and the environment. A greater number of risk-based permit limitations may be necessary when the risk burn and RCRA or MACT performance tests reflect different operating modes.

6.2.1   Volatile Metals (Mercury)

The MACT rule regulates mercury as a volatile metal. EPA considers mercury to be a high priority hazardous air pollutant with the potential to cause significant human health and environmental effects (EPA 1996a, 1997a and 1999c). Mercury is the most volatile regulated metal, is the most difficult metal to control, and has been the subject of many detailed studies, including the *Mercury Study Report to Congress* (EPA 1997a).

At temperatures found in hazardous waste combustion devices, nearly all mercury volatilizes to form gaseous mercury that includes both elemental (reduced) and divalent (oxidized) forms (EPA 1999d). Partitioning between elemental and divalent mercury is critical, because it directly affects the ability to control mercury in the APCD system (EPA 1999d). In general, the divalent form of mercury is more likely to be removed in the APCD.

Mercury speciation is dependent on both the fuel and physical characteristics of the combustor, and may vary for an individual unit as feed and operating conditions change. Mercury speciation in the flue gas depends on factors such as waste composition (in particular, chlorine and sulfur levels), the flue gas temperature profile, and the type of air pollution control (EPA 1999d). If chlorine is not present or if sulfur levels are high, elemental mercury can comprise a significant fraction of the total mercury. Elemental mercury is not soluble in water, and is usually not well controlled by wet scrubbers. Control of elemental mercury may involve the use of an adsorption technology, such as carbon injection.

In the presence of chlorine, formation of divalent mercuric chloride is thermodynamically favored in combustion systems. Mercuric chloride is soluble in water and is readily captured by wet scrubbers. Slow gas cooling (instead of rapid quenching) has been shown to maximize the levels of soluble mercuric chloride and increase wet scrubber performance.

Mercury emissions are primarily controlled by limiting feed rate and through the use of air pollution control techniques involving adsorption or absorption (e.g., carbon technologies and wet scrubbers). MACT control parameters related to mercury emissions from hazardous waste combustion facilities include the following (EPA 1999e):

- C   Mercury emissions increase with increasing mercury feed rate. The MACT rule (EPA 1999c) requires that limits be established for total maximum mercury feed rate to the unit (including hazardous waste, raw materials, and fossil fuels). A separate limit for pumpable feed streams is not necessary, since mercury is highly volatile in any form.

- C   Chlorine feed rate may affect mercury emissions when wet scrubbers are used as APCDs. In the case of mercury, the presence of chlorine is expected to decrease emissions through conversion to the soluble divalent species. However, because only *de minimis* levels of chlorine are necessary for mercury conversion to the soluble salt, minimum chlorine limits are not recommended. A maximum chlorine limit is typically established for most metals

(because increased levels of chlorine can increase metal volatility). However, a maximum chlorine limit is not necessary for mercury, since mercury is already volatile.

C   Combustion chamber temperature is not believed to be a critical operating parameter. At typical mercury feed rates and combustion temperatures, all mercury vaporizes in the combustion chamber.

C   Wet scrubbers have been demonstrated to be effective at controlling water soluble forms of mercury. The MACT rule (EPA 1999c) requires that limits be established for operating parameters associated with wet scrubbers (such as minimum pressure drop across the scrubber, minimum liquid feed pressure, and minimum liquid-to-flue-gas ratio). Gaspar and others have observed that rapid quenching of hot flue gases from municipal waste incinerators reduces mercury removal in wet scrubbers (Gaspar and others 1997). They believe that rapid quenching does not allow sufficient residence time for elemental mercury (which is favored at typical incineration temperatures) to shift to soluble mercuric chloride (which is favored at temperatures below approximately 600 EC in the presence of chlorine). This concern is reiterated in a technical support document to the MACT rule (EPA 1999d).

C   Carbon injection and carbon bed technologies may also be used for mercury control. When carbon technologies are used, the MACT rule (EPA 1999c) requires that limits be established for operating parameters associated with those technologies as described in a technical support document to the MACT rule (EPA 1999e).

MACT control parameters for mercury are summarized in Table 6-1. If a facility bases compliance on an assumption of zero SRE, then only mercury feed rate is limited.

In hazardous waste incinerators and boilers, mercury emissions are currently controlled by limiting waste feed rates and, in some cases, by using wet scrubbers designed for acid gas removal. EPA has estimated that the addition of carbon injection or carbon bed technologies could increase mercury removal in incineration systems up to 90 to 99 percent (EPA 1996a).

Cement kilns and lightweight aggregate kilns currently control mercury emissions by limiting mercury feed rate. Raw materials and coal (as an auxiliary fuel) can add to the mercury emissions. Once mercury is in a cement kiln or lightweight aggregate kiln system, it is generally regarded as "uncontrolled," even though mercury SREs have been documented in some cases (EPA 1999d). Currently, cement kilns and lightweight aggregate kilns do not employ adsorptive or absorptive control technologies (e.g., carbon technologies or wet scrubbers), and mercury is typically not contained in clinker or cement kiln dust unless the cement kiln

dust has an elevated carbon content, which is unlikely (EPA 1999d). The mercury SREs which have been reported for cement kilns and lightweight aggregate kilns may be due to measurement uncertainties associated with the very low levels of mercury in the stack gas or feed streams (EPA 1999d).

6.2.2   Semivolatile Metals

MACT regulates lead and cadmium as semivolatile metals. Emissions of semivolatile metals are a function of both feed rate and APCD removal efficiency for fine, submicron particulate matter (Springsteen and others 1997; EPA 1996a, 1997e and 1999d). Wet scrubbers are generally considered more effective at controlling larger particulates, whereas fabric filters, ESPs and ionizing wet scrubber (IWS) devices are considered most effective in removing smaller particulates (Clarke and Sloss 1992; EER 1991; EPA 1999d). MACT control parameters for semivolatile metal emissions from hazardous waste combustion facilities include the following (EPA 1999e):

- C   Semivolatile metal emission rates increase as the metal feed rates increase. The MACT rule (EPA 1999c) requires that limits be established for total maximum semivolatile feed rate to the unit (including hazardous waste, raw materials, and fossil fuels). A separate limit for pumpable feed streams is not necessary, because partitioning between the combustion flue gas and bottom ash or product does not appear to be affected by physical state.

- C   Chlorine increases metal volatility. The MACT rule (EPA 1999c) requires that a limit be established for maximum chlorine feed rate to the unit. The limit is based on total chlorine from all sources, including organic and inorganic chlorine sources.

- C   Higher combustor gas flow rates can increase particulate and metals entrainment. The MACT rule (EPA 1999c) requires that a limit be established on maximum gas flow rate or kiln production rate.

- C   Maximum combustion chamber temperature has traditionally been established under the BIF rule to control metal volatility. However, maximum combustion chamber temperature is less important than other operating parameters when considering metal emissions from most hazardous waste combustion facilities. For semivolatile metals, typical combustion temperatures are generally high enough to volatilize most of the metals in the combustion chamber, and evaluation of emissions data does not provide any support for a relationship between combustion chamber temperature and semivolatile metals emissions levels (EPA 1999e).

- C   APCD type and operating parameters are recognized as critical to the control of

semivolatile metals, and the MACT rule (EPA 1999c) requires that limits be established on APCD parameters. In addition, the operating temperature of the APCD may also be important. For metals which volatilize in the combustion chamber and are carried out with the flue gas, the APCD temperature affects the degree of condensation and control (lower temperatures result in a higher degree of condensation and control). The MACT rule (EPA 1999c) requires that a limit be established on maximum inlet temperature to the dry APCD to control semivolatile metals emissions.

C   Cement kilns and lightweight aggregate kilns that recycle collected particulate matter should receive special consideration to ensure that emissions reach steady-state prior to testing, as described in two earlier EPA documents (EPA 1992b and 1999c).

MACT control parameters for semivolatile metals are summarized in Table 6-1. If a facility bases compliance on an assumption of zero SRE, then only total semivolatile feed rate is limited.

In hazardous waste incinerators and boilers, semivolatile metals emissions are most effectively controlled by limiting waste feed rates and utilizing APCD systems that control fine particulate matter (i.e., fabric filters, ESPs, and IWS devices). Units equipped with wet scrubbers are typically less efficient at controlling semivolatile metals. A few incinerators and boilers are not equipped with any air pollution control systems, and therefore rely strictly on feed rate control.

Hazardous waste burning cement kilns and lightweight aggregate kilns currently control semivolatile metal emissions by limiting waste feed rates and utilizing fabric filters or ESPs. It is also speculated that certain raw material constituents preferentially bind with semivolatile metals, providing additional control. Semivolatile metals behavior varies to some extent in cement kilns, depending on the particular system configuration. For kilns with in-line raw mills, semivolatile metals emissions are generally lower when the in-line raw mill is operating, due to additional scavenging of vapors in the low temperature raw mill. For short, dry cement kilns equipped with alkali bypass stacks, the majority of semivolatile metals concentrate in the bypass APCD. Semivolatile metals concentrate preferentially in the bypass due to an internal recycle where metals vaporize at kiln temperatures and condense in the preheater towers (EPA 1999d).

6.2.3   Low-Volatile Metals

MACT regulates arsenic, beryllium and total chromium as low-volatile metals. Emissions of low-volatile metals are a function of both feed rate and APCD efficiency for particulate matter (EPA 1997e and 1999d). MACT control parameters associated with the low-volatile metals are consistent with those for the semivolatile metals described in Section 6.2.2, with the following exceptions (EPA 1999e):

C   The MACT rule (EPA 1999c) requires that a separate limit be established for low-volatile metals in pumpable feed streams, since these may partition at a higher rate to the combustion flue gas. However, if a facility wants to base their total feed rate limit only on the feed rate of the pumpable waste feed streams during the test, then separate feed rate limits for total and pumpable feed streams are not needed.

C   Low-volatile metals are less apt to vaporize completely at typical combustion temperatures. Thus, a limit on maximum combustion temperature could theoretically be more important for low-volatile metals than for semivolatile metals. However, the amount of additional vaporization at slightly higher temperatures could be negligible compared to the amount of metals contained in entrained flue gas particulate matter, especially for kilns and pulverized coal boilers. Thus, maximum combustion chamber temperature is most likely less important than APCD operating parameters. In addition, analysis of emissions data does not indicate a strong relationship between combustion chamber temperature and low-volatile metal emissions levels (EPA 1999e).

MACT control parameters for low-volatile metals are summarized in Table 6-1. If a facility bases compliance on an assumption of zero SRE, then only total low-volatile metal feed rate is limited.

Similar to the semivolatile metals, operation of the APCD is critical to removal of low-volatile metals. In cement kilns, a significant fraction of the low-volatile metals partitions to the clinker product. Low-volatile metals do not tend to become concentrated in cement kiln bypass gases or build up an internal recycle to the same extent as semivolatile metals. There is also no strongly expected influence of in-line raw mill operational status on low-volatile metal emissions from cement kilns (EPA 1999d).

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
VOLATILE METAL CONTROL PARAMETERS (MERCURY)					
Feed Rate	Maximum total mercury feed rate in all feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	
Wet Scrubbers High Energy: - venturi - hydrosonic - collision - free jet Low Energy: - spray tower - packed bed - tray tower	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	High energy scrubbers: minimum pressure drop across scrubber	Comprehensive performance test	1 hour	Average of the test run averages	
	Low energy scrubbers: minimum pressure drop across scrubber	Manufacturer specifications	1 hour	N/A	
	Low energy scrubbers: minimum liquid feed pressure	Manufacturer specifications	1 hour	N/A	
	Minimum liquid pH	Comprehensive performance test	1 hour	Average of the test run averages	
	Minimum liquid scrubber flow rate and maximum flue gas flow rate or minimum liquid/gas ratio	Comprehensive performance test	1 hour	Average of the test run averages	
	Ionizing wet scrubbers: minimum power input	Comprehensive performance test	1 hour	Average of the test run averages	

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS (Continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
VOLATILE METAL CONTROL PARAMETERS (MERCURY)					
Activated Carbon Injection	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	Minimum carbon feed rate	Comprehensive performance test	1 hour	Average of the test run averages	
	Minimum carrier fluid flow rate or nozzle pressure drop	Manufacturer specifications	1 hour	N/A	
	Identification of carbon brand and type or adsorption properties	Comprehensive performance test	N/A	Same properties based on manufacturer specifications	
	Good particulate matter control	See control parameters listed for wet scrubbers, fabric filters, ESPs, and IWS devices under semivolatile metals			
Activated Carbon Bed	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	Determination of maximum age of each carbon segment	Comprehensive performance test	N/A	Maximum age of each segment during testing	Age limits may be based on manufacturer specifications for the initial performance test

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS (Continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
VOLATILE METAL CONTROL PARAMETERS (MERCURY)					
Activated Carbon Bed (continued)	Identification of carbon brand and type or adsorption properties	Comprehensive performance test	N/A	Same properties based on manufacturer specifications	
	Maximum gas temperature at the inlet or exit of the bed	Comprehensive performance test	1 hour	Average of the test run averages	
	Good particulate matter control	Same as for activated carbon injection			
SEMIVOLATILE METAL CONTROL PARAMETERS (Pb, Cd)					
Feed Rate	Maximum total semivolatile metal feed rates from all feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	
Chlorine	Maximum total chlorine feed rate from all feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	
Gas Flow Rate	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
Inlet Temperature to Dry Particulate Matter Control Device	Maximum temperature	Comprehensive performance test	1 hour	Average of the test run averages	

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS (Continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
SEMIVOLATILE METAL CONTROL PARAMETERS (Pb, Cd)					
Wet Scrubber: High Energy and Ionizing Scrubbers	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	For high energy wet scrubbers only, minimum pressure drop across scrubber	Comprehensive performance test	1 hour	Average of the test run averages	
	For high energy wet scrubbers only, minimum scrubber liquid flow rate and maximum flue gas flow rate, or minimum liquid/gas ratio	Comprehensive performance test	1 hour	Average of the test run averages	
All Wet Scrubbers	Minimum blowdown rate and minimum scrubber tank volume or level, or	Comprehensive performance test	1 hour	Average of the test run averages	
	Maximum solids content of water	Comprehensive performance test	12 hour for continuous monitor	Average of the test run averages	
			1 hour for manual sampling	Average of manual sampling run averages	

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS (Continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
SEMIVOLATILE METAL CONTROL PARAMETERS (Pb, Cd)					
Fabric Filter	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	Minimum pressure drop and maximum pressure drop across each cell	Manufacturer specifications	1 hour	N/A	
Electrostatic Precipitator and Ionizing Wet Scrubber	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	Minimum power input (kVA) based on secondary voltage and current to each field	Comprehensive performance test	1 hour	Average of the test run averages	
LOW-VOLATILE METAL CONTROL PARAMETERS (As, Be, Cr)					
Feed Rate	Maximum total low-volatile metal feed rates from all feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	
	Maximum total low-volatile metal feed rates from all pumpable feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	See Section 6.2.2
Chlorine	Same as semivolatile metals				

TABLE 6-1

MACT CONTROL PARAMETERS ASSOCIATED WITH METALS EMISSIONS (Continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
LOW-VOLATILE METAL CONTROL PARAMETERS (As, Be, Cr)					
Gas Flow Rate	Same as semivolatile metals				
Inlet Temperature to Dry Particulate Matter Control Device	Same as semivolatile metals				
Wet Scrubber: High Energy and Ionizing Scrubbers	Same as semivolatile metals				
All Wet Scrubbers	Same as semivolatile metals				
Fabric Filter	Same as semivolatile metals				
Electrostatic Precipitator and Ionizing Wet Scrubber	Same as semivolatile metals				

Notes: As   =   arsenic   ESP   =   electrostatic precipitator   Pb   =   lead
            Be   =   beryllium   IWS   =   ionizing wet scrubber   MACT =   maximum achievable control technology
            Cd   =   cadmium   kVA   =   kilovolt-amperes   N/A   =   not applicable
            Cr   =   total chromium

[1]   =   This limit applies to all feed streams except natural gas, process air, and feed streams from vapor recovery systems, provided that expected levels of constituents in those feed streams are accounted for in documenting compliance with feed rate limits. See the MACT rule preamble (EPA 1999c) for further information.

6.3   RISK-BASED LIMITATIONS

The MACT control parameters discussed in Section 6.2, or similar parameters under the BIF rule, either apply or will apply to most hazardous waste combustors. However, risk-based limitations beyond these regulatory requirements may be necessary to protect human health and the environment for some facilities. This section addresses potential site-specific risk-based controls beyond BIF or MACT, with emphasis on metal feed rate and emissions restrictions. Since there is generally a strong relationship between metals emissions and feed rates, feed rate reduction is expected to be the primary means of achieving a more stringent risk-based metal emissions level if necessary.

Several topics are addressed in this section. Site-specific risk-based emissions and feed rate limitations for regulated metals (i.e., metals specifically controlled under either BIF or MACT) are discussed in Section 6.3.1. Restrictions for other potentially toxic metals which are not specifically enumerated in the BIF or MACT regulations, but which may be COPCs for site-specific risk assessments, are discussed in Section 6.3.2. Special considerations related to acute risks are discussed in Section 6.3.3. Finally, the use of extrapolation and metals surrogates for establishing site-specific risk-based feed rate limits is discussed in Sections 6.3.4 and 6.3.5, respectively.

Although the metal control parameters discussed in Section 6.2 were presented in terms of metal volatility groups, this guidance does not recommend that risk-based permit limits be established for metal volatility groups (rather than individual metals). The divisions between volatility groups are not absolute. More importantly, EPA OSW has recommended that individual metals be modeled separately for risk assessments using the fate and transport parameters and toxicity information specific to each metal (EPA 1998a and 1999b). The use of volatility groupings for risk-based permitting should generally be limited to the metal extrapolation and surrogate applications discussed later in Sections 6.3.4 and 6.3.5.

6.3.1   Regulated Metals

As noted at the beginning of Section 6.2, the metals emissions standards that apply to hazardous waste combustors vary considerably, depending on the type of combustion device and the time frame being

considered. In assessing the need for risk-based controls, a permit writer will need to consider which regulatory standards apply to a particular facility for which metals, and whether the applicable standards are expected to change over time. Boilers, cement kilns and lightweight aggregate kilns are currently subject to standards for ten BIF metals (antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium). Nickel and selenium have also been regulated at some facilities through omnibus authority of RCRA (EPA 1992a). For cement kilns and lightweight aggregate kilns, the BIF standards for mercury, lead, cadmium, arsenic, beryllium, and chromium will be superseded by MACT technology-based metals standards, and a MACT technology-based particulate standard will serve as surrogate control for antimony, cobalt, manganese, nickel and selenium. The three remaining BIF metals (barium, silver and thallium) are not hazardous air pollutants under the Clean Air Act, and so do not have MACT limits. For hazardous waste incinerators, MACT standards for mercury, lead, cadmium, arsenic, beryllium, chromium and particulate matter will apply. MACT standards for hazardous waste burning boilers have not yet been developed, and thus will not apply until a future rulemaking has been completed.

The particular regulatory standards which apply at a given facility will inform decisions regarding the need for supplemental risk-based permit conditions, as well as the type of supplemental risk-based permit conditions which may be appropriate. For example, it may be necessary to supplement the BIF standards to protect human health and the environment because the BIF standards may not sufficiently protect against risks via indirect exposure routes, or because the BIF standards may not reflect current toxicological information. Lower emissions and feed rate limits for mercury may be necessary to assure protection of human health and the environment because of its propensity to bioaccumulate, and for nickel, because of potential carcinogenic risks through the direct inhalation exposure route (EPA 1998a and 1999b). The MACT standards are viewed as more stringent than the RCRA 40 CFR Part 266 Subpart H standards for BIFs (EPA 1999c). However, risk-based controls to supplement the MACT standards may be appropriate on a site-specific basis. Lower emissions and feed rate limits for certain metals may be appropriate at some sites to assure protection of human health and the environment. In addition, fewer metals are directly regulated under MACT (for some metals, a particulate matter standard serves as a surrogate control measure), and risk-based controls for the non-regulated metals and for the indirectly controlled metals may need to be considered, as discussed in Section 6.3.2. Finally, the MACT rule provides an option for alternative standards at cement kilns and lightweight aggregate kilns when the MACT metal emissions

standards cannot be achieved because of metals in the raw materials. The alternative standards represent another scenario where MACT may need to be supplemented with site-specific risk-based limits to ensure that a facility does not pose an unacceptable risk (EPA 1999c).

A preliminary risk assessment can provide information to determine whether operation within regulatory emissions limits (either BIF or MACT) may present a significant risk to human health and the environment. As discussed in Section 3.2, EPA OSW recommends that the preliminary risk assessment be performed prior to the risk burn to better define the risk burn data needs. If a regulatory limit applies for a particular metal and is sufficiently protective, additional risk-based limits should generally not be needed. However, if the regulatory limit for a particular metal is not sufficiently protective, a lower, site-specific risk-based emissions limit for that metal may need to be established in the RCRA permit to assure protection of human health and the environment.

In addition to providing information on whether operation within a regulatory emissions limit may present a significant risk to human health and the environment, the preliminary risk assessment can also indicate the extent of emissions reduction necessary to assure protection of human health and the environment. After a protective emissions limit has been defined, a correspondingly lower metal feed rate limit can be determined. A variety of methodologies can be used to establish a risk-based feed rate limit from a risk-based emissions limit. Several approaches are outlined below, and a combination of methodologies may be appropriate in some cases:

C   Zero SRE: A facility may choose to establish a risk-based feed rate limit from the risk-based emissions limit for a particular metal by assuming zero SRE (i.e., the feed rate limit is the same as the risk-based emissions rate limit).

C   Existing SRE: A facility may have data from an existing SRE test performed for BIF or MACT documenting that the lower, risk-based emissions limit is already being achieved. In this case, the risk-based metal feed rate limit is the same as the feed rate during the SRE test where the risk-based emissions limit was demonstrated.

C   New SRE: With careful planning, a future SRE test may serve as the vehicle for determining risk-based feed rate limits. For example, a facility may be due for BIF re-certification testing, or may be about to perform the initial MACT performance test. If the facility has performed a preliminary risk assessment which indicates the need for risk-based controls, the facility may be able to reduce (or eliminate) metals spiking, as well as perform sampling for

additional non-regulated metals, to meet the objectives of both the performance test and the risk burn. In this case, the risk-based metal feed rate limit is established as the feed rate during the SRE test where the risk-based emissions limit is demonstrated.

C <u>Normal Test</u>: Where appropriate (see Section 3.3.2.2), a separate test conducted at normal metal feed rates may be considered for establishing risk-based metal feed rate limits. When metals emissions data collected during a normal test are utilized for the site-specific risk assessment, a dual testing and permitting scheme such as the following is recommended:

  S An SRE test is performed to demonstrate that maximum emissions meet applicable BIF or MACT limits, and to establish maximum hourly or 12-hour feed rate limits

  S A normal test is performed to generate emissions data for evaluation in the site-specific risk assessment, and to establish long-term average feed rate limits

C <u>Extrapolated Feed Rate</u>: The use of extrapolation to establish risk-based feed rate limits is discussed further in Section 6.3.4. Opportunities for using extrapolation to establish risk-based feed rate limits may be somewhat limited, since only upward extrapolation is recommended (whereas risk-based permitting involves *lowering* feed rates). However, some situations may be amenable to extrapolation. For example, a facility may have collected data for the entire suite of metals during a previous SRE test (even though only a few metals were spiked). Upward extrapolation for the unspiked metals could be considered.

C <u>Surrogate SRE</u>: The use of surrogates to establish risk-based feed rate limits is discussed further in Section 6.3.5. If existing metals emissions data are available, but data on a certain metal were not collected, or if the data for a particular metal are not useful (i.e., an SRE cannot be determined because of non-detects for the feed inputs), use of data for a surrogate metal based on volatility groupings may be considered.

The approach selected to establish risk-based metal feed rate limits from risk-based emissions limits will affect the scope of the risk burn. For example, if a facility chooses the "Zero SRE" approach for all metals where risk-based limits are needed, then metal emissions measurements may not be needed during the risk burn. However, if a facility chooses the "Normal Test" approach, the risk burn may involve extra test conditions.

Under any of these options, EPA OSW recommends that an averaging period for the risk-based feed rate limit be specified. A facility may choose to comply using the same feed rate averaging periods as specified by BIF or MACT (1 hour or 12 hours) to minimize need for extra monitoring. On the other hand, if these averaging periods do not allow sufficient operating flexibility, a facility may choose to comply using a

longer-term averaging period. Long-term metal feed rate averaging periods should generally be adequate for controlling long-term, chronic risks, as discussed in Section 3.3.2.2.

6.3.2   Other Toxic Metals

In addition to the original ten BIF metals, other metals that EPA OSW has recommended be considered as COPCs for site-specific risk assessments include aluminum, cobalt, copper, manganese, nickel, selenium, vanadium, and zinc (EPA 1998a and 1999b). Summaries of specific human health and ecological concerns for these metals are found in Section 2.3 of this document.

For these eight metals (if a facility is subject to BIF) and for twelve metals (if a facility is subject to MACT), specific regulatory restrictions on metal emissions or feed rates do not apply (although MACT does establish a particulate matter standard as a surrogate control measure for antimony, cobalt, manganese, nickel, and selenium). EPA OSW recommends that the need for risk-based restrictions on these metals be determined on a site-specific basis, considering the potential risks associated with the metals. A preliminary risk assessment can provide an indication as to whether specific feed rate controls on these metals may be necessary. As discussed in Section 3.2, EPA OSW recommends that the preliminary risk assessment be performed prior to the risk burn to better define the risk burn data needs.

To perform a preliminary risk assessment, initial emissions estimates for the non-BIF or non-MACT metals are needed. Actual emissions data may not be available, since some of these metals have never been subject to specific regulatory emission or feed rate standards. In the absence of actual emissions data, a facility might consider performing the preliminary risk assessment based on the assumption that the non-regulated metals are fed at normal feed rates (considering the composition of the wastes burned at the facility) and are completely emitted (i.e., zero SRE). If a preliminary risk assessment indicates that risks may be significant (for nickel, for example, which may be evaluated in the risk assessment as a carcinogen per the EPA OSW risk assessment guidance [EPA 1998a]), emissions sampling during the risk burn may be appropriate.

The need for risk-based controls on the non-BIF/non-MACT metals will generally depend on whether emissions of these metals are predicted to present a significant risk to human health and the environment. If

potential risks associated with the metals are insignificant, a permit writer may simply choose to document the risk assessment feed and emissions assumptions in the administrative record instead of imposing specific feed rate limits in the permit. As risks from non-BIF/non-MACT metals approach significant levels, feed rate monitoring and tracking may be necessary for protection of human health and the environment by ensuring that potentially significant changes in feed rates which could warrant re-evaluation in the risk assessment are identified. Alternatively, risk-based emissions limits and long-term average feed rate limits may be established in the permit.

As discussed in Section 6.3.1 for BIF/MACT metals, a variety of methodologies can be used to establish risk-based feed rate limits from risk-based emissions limits. The same options listed in Section 6.3.1 may be appropriate for the non-BIF/non-MACT metals. It is generally anticipated that feed rates of these metals will not need to be limited on a short-term (i.e., 1 or 12 hour) basis, but that long-term average feed rate limits will be sufficient. In addition, testing for these metals will not typically involve spiking.

6.3.3   Acute Risks

Sections 6.3.1 and 6.3.2 discuss establishing site-specific risk-based emissions limits and corresponding feed rate limits, with options involving testing at normal conditions and performing feed rate monitoring using long-term averaging periods. Testing at normal conditions and applying long-term averaging periods may be appropriate for the purpose of controlling long-term, chronic risk from metals. However, the EPA OSW risk assessment guidance (EPA 1998a) also recommends an evaluation of acute risk associated with short-term (maximum 1 hour) exposure through the inhalation pathway. The acute evaluation is based on an estimate of maximum potential 1-hour metal emissions rates. The normal test option mentioned in Sections 6.3.1 and 6.3.2 would not be appropriate for generating maximum emissions estimates for an acute evaluation, and other options may need to be considered. Also, if acute risks at maximum emissions rates appear to be a concern for a particular metal, then a maximum 1-hour feed rate limit may need to be established in the permit (in addition to the longer-term feed rate limit which may be established per Sections 6.3.1 and 6.3.2 to control chronic risks).

6.3.4 Extrapolation

As discussed in Section 6.3.1, one option for establishing risk-based feed rate limits from risk-based emissions limits involves the use of extrapolation (subject to approval). Extrapolation involves using test data collected at one metals feed rate to project an emissions level at a different metals feed rate. "Upward" extrapolation refers to projecting the emissions associated with a higher metals feed rate, whereas "downward" extrapolation refers to projecting the emissions associated with a lower metals feed rate. Extrapolation is of interest because: 1) it potentially eliminates the need to re-test at different metals feed rates to show compliance with more stringent risk-based emission limits; and 2) it can help to minimize the need for metals spiking.

Trends in facility-specific data (EPA 1997e) support the following observations, as illustrated in Figure 6-1:

- C   Emissions tend to increase as feed rate increases;

- C   The relationship between emissions and feed rate for volatile and semivolatile metals tends to be stronger than that for low-volatile metals (i.e., there is a more proportional relationship between emissions and feed rates for volatile and semivolatile metals);

- C   The relationship between emissions rate and feed rate for low-volatile metals tends to be more flat (not a strong function of feed rate). SRE strongly tends to increase with increasing feed rate for low-volatile metals.

Given these trends, EPA has determined that upward extrapolation from the origin (i.e., from a metal feed rate and emissions rate of zero) is conservative for all metal types and volatilities, as illustrated in Figure 6-3 (EPA 1997e). Upward extrapolation is conservative because the predicted emissions rates at higher feed rates are likely to be equal to or greater than actual emissions rates. SRE tends to stay the same or increase with increasing feed rate. However, as also illustrated in Figure 6-3, downward extrapolation may not always be conservative. Downward extrapolation may result in predicted emissions that are less than actual emissions. Thus, downward extrapolation is generally not recommended. Downward extrapolation for low-volatile metals can be particularly problematic, because there is not a strong linear relationship between emissions and feed (see Figure 6-1).
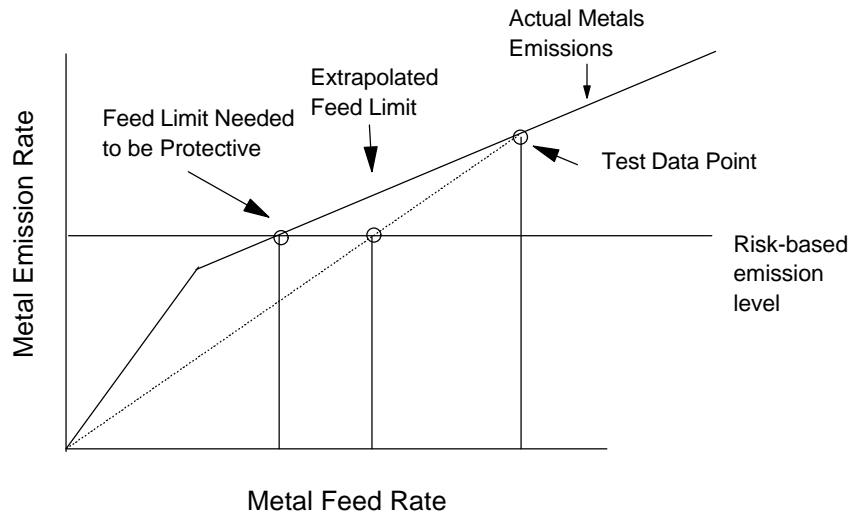
FIGURE 6-3

METALS EXTRAPOLATION

Upward Extrapolation
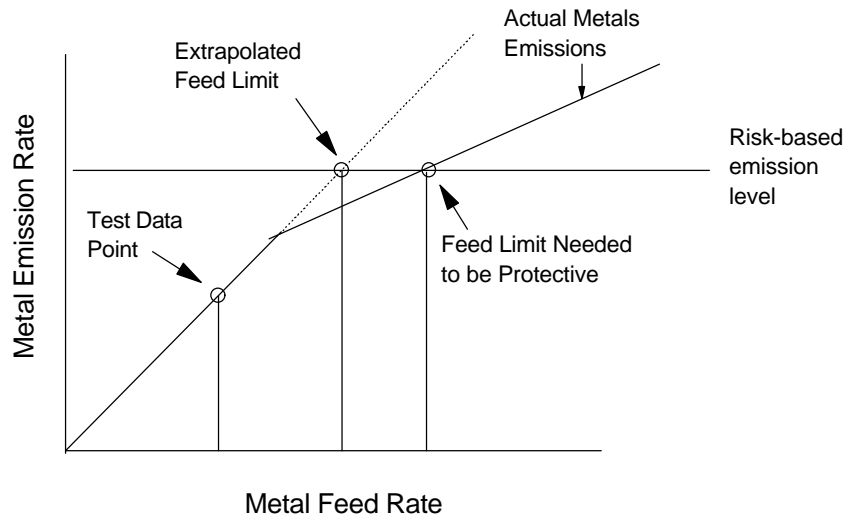
Downward Extrapolation

Since only upward extrapolation is recommended as being conservative, the opportunities for using extrapolation to establish risk-based feed rate limits may be somewhat limited. Risk-based permitting generally involves *lowering* emissions and feed rates (i.e., downward extrapolation). However, some risk-based permitting situations may be amenable to upward extrapolation. For example, a facility may have collected emissions data for unspiked metals during a previous SRE test. Upward extrapolation for the unspiked metals could be considered. In reviewing a proposal to use extrapolation for establishing risk-based feed rate limits, the permitting authority should generally consider information similar to the guidelines specified in the hazardous waste combustor MACT rule and supporting documents (EPA 1999c and 1999e):

C   **Is there sufficient confidence in the test data being used for the extrapolation?** Upward extrapolation to establish a risk-based metal feed rate limit is likely to involve the use of test data where spiking was not performed. However, there may be a high degree of uncertainty associated with this type of data. At low concentrations, the error bounds on the sampling and analysis procedures tend to be more significant. Errors associated with sampling and analysis for heterogeneous feed streams can be particularly high. In addition, it may not be possible to calculate an SRE at all if a metal is not detected in one or more of the feed streams. In determining whether there is sufficient confidence in the test data being used for the extrapolation, it is recommended that the permit writer consider the incidence and potential impact of non-detect data points, as well as the reproducibility between test runs.

C   **Are the requested feed rates warranted?** A permit writer should generally not approve extrapolation to feed rates that are significantly higher than the historical range of feed rates, unless a facility documents that future operations will necessitate higher metals feed rate limits.

A variety of metal extrapolation procedures have been proposed over the years (EPA 1992b, 1997d, 1997e, 1999c and 1999e; Springsteen and others 1997). It is recommended that available feed and emissions data be plotted graphically before a decision is made regarding the suitability of extrapolation and a specific extrapolation method. A graphical representation can assist in identifying non-linear behavior, high data variability, and potential outliers. It may also be useful to plot metals within the same volatility group on the same graph. A combined plot can support a determination of whether metals in the same volatility group behave similarly (as would theoretically be expected), and a wider range of feed rates for a particular volatility group may be represented when the data for several metals are grouped together.

The permit writer should generally ensure that a proposed extrapolation procedure will be appropriately conservative, considering the extent and quality of the metals feed rate and emissions data. Depending on a review of the actual data, a conservative extrapolation procedure might include:

Ⅽ Extrapolation from the lowest observed SRE that is not an outlier. The lowest SRE can either be determined for an individual metal, or it might be selected based on the collective data for metals within a given volatility group. Provided that the grouped data confirm that the metals behave similarly, a wider range of feed rates may be represented when the data for several metals are grouped together.

Ⅽ Extrapolation from the "Lower Confidence Limit" of the test condition average SRE for a particular metal, calculated based on the test condition average and the within-test-condition standard deviation at a particular confidence limit bound (such as 95 percent).

Ⅽ For cases where data for a particular metal are more extensive (for example, if repeated tests have been conducted over the years), extrapolation from a statistically-based analysis of the entire database.

A permit writer may choose to disapprove extrapolation if there is not a high degree of confidence that average emissions at the extrapolated feed rate will be at or below the risk-based emissions rate. Alternatively, a permit writer may choose to condition the extrapolation on performance of follow-up testing to confirm that the risk-based emissions levels are being achieved, or to limit the extent of extrapolation, or to limit the proximity of the extrapolation to the risk-based emissions limit.

Section 6.2.3 explains that the MACT rule requires that separate feed rate limits be established for low-volatile metals in total feed streams and for low-volatile metals in pumpable feed streams, since metals in the pumpable feed streams may partition at a higher rate to the combustion flue gas. When extrapolation is performed to establish a total risk-based feed rate limit for a low-volatile metal, the permit writer should also generally consider whether a separate feed rate limit is appropriate for pumpable feed streams and, if so, how to establish that limit. One option is to maintain the pumpable and total feed rate ratio the same for the extrapolated feed rates as in the original data used for the extrapolation. Another, very conservative, option is to base the total extrapolated feed rate limit only on extrapolation from the feed rate of the pumpable feed stream. In this later case, separate feed rate limits for total and pumpable streams should not be needed.

6.3.5   Surrogate SREs

As discussed in Section 6.3., another option for establishing risk-based feed rate limits from risk-based emissions limits involves the use of SREs for surrogate metals. The use of an SRE for a surrogate metal may be appropriate in several situations. For example, if existing metals emissions data are available, but data were not collected for a particular metal, or if the data for a particular metal are not useful (i.e., an SRE cannot be determined because of non-detects for feed inputs), the use of a surrogate SRE may be appropriate. In addition, use of surrogate SREs may be considered to limit the need for spiking during a risk burn if certain metals are not normally present in the feed streams at reliable levels.

In reviewing a proposal to use surrogate SREs for establishing risk-based feed rate limits from risk-based emissions limits, EPA OSW recommends that the permitting authority consider whether one metal is an appropriate surrogate for another. In general, metals within a volatility grouping can be used interchangeably for each other, and metals of a "higher" volatility grouping can be used as surrogates for metals in a lower grouping. Figure 6-2 depicts the relative volatility for sixteen of the potentially toxic metals discussed in Section 2.3.   Springsteen and others provide further analysis based specifically on trends in hazardous waste combustor data (Springsteen and others 1997). Springsteen categorizes mercury and selenium as "volatile" metals in hazardous waste combustor systems. This categorization compares favorably with the Group 3 metals in Figure 6-2, reproduced from Clark and Sloss (Clark and Sloss 1992). These metals tend to vaporize completely at combustion temperatures. Mercury may remain volatile in the APCD, while selenium is more likely to condense. Because of its behavior in the APCD, selenium is often treated as a semivolatile metal (although it is the most volatile metal in that category, as indicated by Figure 6-2). Selenium may not completely fit within either category.

Springsteen and others categorize cadmium, lead and thallium as "semivolatile" (Springsteen and others 1997). This categorization compares favorably with the Group 2 metals identified in Figure 6-2, reproduced from Clark and Sloss (Clark and Sloss 1992).

Springsteen and others categorize barium, beryllium, chromium and nickel as "low-volatile" (Springsteen and others 1997). Figure 6-2 also places these metals in the Group 1 low-volatile metal category. However, in

Figure 6-2, these metals fall in the area of the circle that overlaps with the Group 2 semivolatile metal category, indicating that partitioning behavior may vary for different combustion systems with different operating conditions. Facility-specific data should generally be reviewed to determine whether any of these metals exhibit semivolatile metal behavior (as evidenced by more enrichment of these metals in air pollution control residues than in bottom ash or clinker residues). Or, in the absence of site-specific information, these metals could be treated conservatively as semivolatile metals.

Finally, Springsteen and others explain that three metals exhibit low-volatile behavior in cement kilns but may behave more like semivolatiles in incineration systems (Springsteen and others 1997). These metals include arsenic, antimony, and silver. Springsteen includes special recommendations for arsenic, antimony, and silver, since their behavior can be dependent on combustion system type (Springsteen and others 1997). In cement and lightweight aggregate kilns, these metals are included within the low-volatile grouping, and all low-volatile metals can be used interchangeably as surrogates for each other. In incinerators and boilers, arsenic, antimony, and silver can conservatively be used as surrogates for low-volatile metals, but low-volatile metals generally should not be used as surrogates for arsenic, antimony, and silver. In addition, arsenic, antimony, and silver generally should not be used as surrogates for each other for incinerators and boilers.

EPA OSW recommends that the general guidelines regarding specific metals and volatility groupings always be reviewed in conjunction with facility-specific data. Volatile metals will not be present in significant concentrations in either fly ash or bottom ash. Semivolatile metals are more likely to be enriched in air pollution control residues such as fly ash (or cement kiln dust), and low-volatile metals are more likely to be enriched in the bottom ash (or clinker).

It is important to recognize that use of a surrogate SRE will often involve extrapolation, and the concepts presented in Section 6.3.4 apply. That is, "upward" extrapolation is usually conservative, but "downward" extrapolation may not be. Therefore, an SRE determined at a higher feed rate for one metal should generally not be used to calculate a lower feed rate for a surrogate metal. In addition, the permit writer should feel comfortable that use of a surrogate SRE will be appropriately conservative, considering the extent and quality of the metals feed rate and emissions data. A conservative approach may involve:

C   Use of the lowest observed SRE that is not an outlier. The lowest SRE can either be
        determined for an individual metal, or it might be selected based on the collective data for
        metals within a given volatility group. Where the grouped data confirms that the metals
        behave similarly, a wider range of feed rates may be represented when the data for several
        metals are grouped together.

C   Use of the "Lower Confidence Limit" of the test condition average SRE for a particular
        metal, calculated based on the test condition average and the within-test-condition standard
        deviation at a particular confidence limit bound (such as 95 percent).

C   For cases where data are more extensive (for example, if repeated tests have been conducted
        over the years), it may be appropriate to perform a statistically-based analysis of the entire
        database to determine a conservative SRE.

6.4   METAL SPECIATION

The mobility, bioavailability and toxicity of a metal varies, depending on the specific chemical compound.
However, the ability to measure individual metal compounds and to assess the risks associated with those
compounds is currently limited. EPA OSW's human health and ecological risk assessment guidance
documents (EPA 1998a and 1999b) generally address metals in the elemental form, with the exception of
mercury, chromium, and nickel. For mercury, chromium and nickel, the guidance (EPA 1998a and 1999b)
provides recommended assumptions regarding valence state or chemical form. Based on the conservative
nature of these assumptions, a facility may want to perform speciation sampling during the risk burn or
present other information to replace the recommended assumptions with site-specific data.

6.4.1   Mercury

As discussed in Section 6.2.1, mercury can be present in the divalent (oxidized) form or the elemental
(reduced) form. The form of mercury significantly influences its fate and transport in the environment. The
divalent form is water soluble and more likely to adsorb to particles. Stack emissions can thus be removed
from the atmosphere by precipitation, which can lead to partitioning into methyl mercury in nearby surface
waters. This partitioning will tend to drive indirect ecological risks and food chain risks to humans.
Elemental mercury, on the other hand, is less prone to rapid atmospheric removal and deposition near the
source. The EPA OSW risk assessment guidance (EPA 1998a and 1999b) assumes that the vast majority

(99 percent) of elemental mercury is diffused to the free atmosphere to become part of the global mercury cycle (rather than being deposited near the source).

The recommended mercury emissions speciation assumptions provided in the EPA OSW risk assessment guidance (EPA 1998a and 1999b) are: 60 percent divalent vapor phase, 20 percent divalent particle-bound phase, and 20 percent elemental vapor phase. The rationale for these assumptions is discussed in greater detail in the EPA OSW risk assessment guidance (EPA 1998a). A facility may wish to perform speciation sampling for mercury during the risk burn to replace the recommended assumptions with site-specific data. For example, some data suggest that the percentage of elemental mercury may be higher for certain units equipped with wet scrubber systems (EPA 1999g).

Standard EPA sampling methods for mercury speciation are not currently available. However, methodologies which have been evaluated for their ability to provide mercury speciation information are discussed in Appendix B of this document. If mercury speciation sampling is performed, care should be taken to avoid operating the unit in a manner which could result in a high bias for the elemental form of mercury. Higher percentages of elemental mercury tend to decrease risks, because the EPA OSW risk assessment guidance (EPA 1998a and 1999b) assumes that only 1% of elemental mercury deposits near the source. As discussed in Section 6.2.1 of this document, elemental mercury can comprise a significant fraction of the total mercury if chlorine levels are low or if sulfur levels are high. In addition, rapid quenching may increase the percentage of elemental mercury because the elemental mercury (which is favored at typical combustion temperatures) may not have sufficient residence time to shift to the divalent form (which is favored at temperatures below approximately 600 EC in the presence of chlorine).

6.4.2   Chromium

Chromium exists in multiple valance states. The hexavalent form is most toxic and has been shown to be a human carcinogen via the direct inhalation exposure route (EPA 1998a). The hexavalent form typically occurs as either chromate or dichromate. Trivalent chromium has not been shown to be carcinogenic in either human or laboratory animals (EPA 1998a). EPA OSW has not recommended that other chromium valence states be considered in risk assessments (EPA 1998a).

Available information suggests that substantial quantities of chromium are not likely to be emitted in the hexavalent form from combustion units. Laboratory work by Linak and others indicates that the fraction of hexavalent chromium emitted may be very small, typically ranging from less than one percent to approximately two percent of the total chromium measured (Linak and others 1996; Linak and Wendt 1998). The hexavalent fraction in the exhaust was found to be enhanced somewhat by high levels of chlorine, but was reduced to below analytical detection limits by the addition of small quantities of sulfur. Additional information indicating low percentages of hexavalent chromium from combustion units is provided by EPA (EPA 1990) and Bailiff and Kelly (Bailiff and Kelly 1990). However, in limited situations and under certain conditions, a high percentage of hexavalent chromium has been found in combustor emissions (EPA 1991).

The recommended chromium emissions speciation assumption provided in the EPA OSW risk assessment guidance (EPA 1998a) is a worst-case assumption (i.e., that 100 percent of the chromium emissions are in the hexavalent form). The basis for this assumption is that there is not sufficient evidence to reliably estimate the partitioning of chromium between the two valence states. The recommended assumption is very conservative. Therefore, a facility may wish to sample for hexavalent chromium during the risk burn to replace the recommended assumption with site-specific data. SW-846 (EPA 1996b) provides an in-stack emissions method (Method 0061) for differentiating between trivalent and hexavalent chromium.

6.4.3   Nickel

Nickel can achieve several oxidation states (up to four), with the most common being +2. The most prevalent forms of nickel are sulfides, oxides, chlorides, and silicates. Some forms of nickel (including nickel carbonyl, nickel subsulfide, and nickel refinery dust) are considered to be carcinogenic. Previously under the BIF regulations, EPA did not treat nickel as a carcinogen because of the presumption that nickel can only be emitted from combustion units as nickel oxide (which, by itself, is not considered to be a carcinogen).

The recommended assumption provided in the EPA OSW risk assessment guidance (EPA 1998a) is that nickel be evaluated as an inhalation carcinogen using the carcinogenic slope factor for nickel refinery dust. This recommendation represents a change from the regulatory approach under the BIF rule. The basis for the revised approach is that nickel oxide is a major component of nickel refinery dust, and the component in nickel refinery dust which causes it to be carcinogenic has not been established. For exposure pathways

other than direct inhalation, EPA OSW has recommended that nickel be evaluated as a noncarcinogen using the oral reference dose for soluble nickel salts (EPA 1998a). A similar approach was utilized in the risk assessment conducted in support of the MACT rule (RTI 1999).

Standard EPA sampling methods for nickel speciation do not exist at this time. Therefore, it is not possible for a facility to generate site-specific stack emissions data to replace the recommended assumptions provided in the EPA OSW risk assessment guidance (EPA 1998a). However, the risk assessment guidance discusses an approach where a facility may present data at potential points of inhalation exposure indicating the absence of carcinogenic nickel refinery dust components or the presence of noncarcinogenic species such as soluble salts.

CHAPTER 7

HYDROGEN CHLORIDE/
CHLORINE EMISSIONS
AND PARTICLE-SIZE DISTRIBUTION

EPA OSW has recommended that hydrogen chloride and chlorine be evaluated for potential risks in site-specific risk assessments (EPA 1998a). Potential risks from HCl and Cl_2 are limited to the inhalation pathway. Since most facilities are either controlling or will control HCl and Cl_2 emissions under the hazardous waste combustor MACT rule, the primary consideration for the risk burn is whether additional control beyond applicable regulatory standards may be warranted at a particular site (see also Sections 1.3.2 and 1.3.3). This chapter (Section 7.1) identifies risk burn data needs and control parameters related to HCl and Cl_2. Since HCl and Cl_2 have been discussed at length in other documents (EPA 1992b, 1999d and 1999e), they are only mentioned briefly here.

This chapter (Section 7.2) also identifies risk burn data needs related to particle-size distribution. Information on particle-size distribution is needed for the air dispersion and deposition modeling that supports risk assessments (EPA 1998a and 1999b).

7.1   HYDROGEN CHLORIDE AND CHLORINE

The HCl and Cl_2 emissions standards which apply to hazardous waste combustors vary, depending on the type of combustion device and the time frame being considered. Technology-based limits for HCl have applied to hazardous waste incinerators since 1981 (40 CFR Part 264.343). The technology-based standards limit HCl emissions to the larger of 4 pounds per hour or 99% removal. The 40 CFR Part 264.343 provisions do not include an emission limit for Cl_2. For hazardous waste burning boilers and industrial furnaces, HCl and Cl_2 emissions have been regulated since 1991 under the BIF rule (40 CFR Part 266, Subpart H). The BIF standards are risk-based standards which consider exposure via the inhalation pathway

based on RACs specified in the regulations. However, updated toxicological information (instead of the RACs specified in 40 CFR Subpart H) may be available and may need to be considered for site-specific risk assessments at BIF facilities. Similar provisions to those prescribed by 40 CFR Subpart H have been applied at some hazardous waste incineration facilities through individual permit decisions pursuant to the omnibus authority of Section 3005(c)(3) of RCRA and 40 CFR 270.32(b)(2). More recently, technology-based MACT emission limits have been promulgated for hazardous waste burning incinerators, cement kilns, and lightweight aggregate kilns (EPA 1999c). The MACT standards establish limits on parts per million volume (ppmv) of HCl and Cl_2 emissions, expressed as HCl equivalents (calculated as ppmv HCl + 2*ppmv Cl_2). Facilities have three years from the MACT rule promulgation date (September 30, 1999) to comply with the revised standards. Upon documentation of compliance with MACT, the RCRA incinerator and BIF emission standards are superseded (however, any RCRA permit requirements or conditions related to the combustor remain in effect until that permit is either modified to remove the conditions or the permit is terminated or expires). Technology-based standards for hazardous waste burning boilers are anticipated in a future MACT rulemaking.

The particular regulatory standards which apply at a given facility will inform decisions regarding the need for supplemental risk-based controls on HCl and Cl_2 emissions, as well as the type of supplemental risk-based permit conditions which may be appropriate. For example, it may be necessary to supplement the 40 CFR Part 264.343 incinerator standards to protect human health and the environment, because Cl_2 emissions are not limited at all by 40 CFR Part 264.343, and because the HCl removal efficiency standard does not equate to a specific emission limitation. It may be necessary to supplement the BIF standards when updated toxicological information (instead of the RACs specified in 40 CFR Subpart H) is available. Risk-based controls to supplement the MACT standards, including lower emissions and feed rate limits, may be appropriate to assure protection of human health and the environment on a site-specific basis.

A preliminary risk assessment can provide information to determine whether operation within a regulatory emissions limit for HCl and Cl_2 (for example, BIF or MACT) may present a significant risk to human health and the environment. Both pollutants are noncarcinogens and pose risks only through the inhalation pathway. As discussed in Section 3.2, EPA OSW recommends that the preliminary risk assessment be performed prior to the risk burn to better define risk burn data needs. If a regulatory limit applies and is sufficiently

protective, additional site-specific risk-based limits should generally not be needed. However, if the regulatory limit is not sufficiently protective, a lower site-specific risk-based emissions limit for HCl or Cl_2 may need to be established in the RCRA permit to assure protection of human health and the environment.

When it is appropriate to establish a lower, site-specific risk-based emission limit for HCl or Cl_2 in the RCRA permit to supplement applicable regulatory standards, then EPA OSW recommends that stack emission measurements for both HCl and Cl_2 be performed to verify the feed and operating conditions necessary for achieving compliance with the more stringent emission limits. HCl and Cl_2 emission levels cannot be predicted from feed rate information or from extrapolation of stack test data because of the difficulty in predicting the partitioning between HCl and Cl_2 at various operating conditions (additional information on HCl and Cl_2 partitioning is provided in a technical support document for the hazardous waste combustor MACT rule, EPA 1999d). The use of existing test data may be appropriate in some cases, particularly if the data already demonstrates compliance with the more stringent risk-based limits. Otherwise, sampling during the risk burn may be appropriate.

EPA OSW recommends that the risk burn for HCl and Cl_2 generally be conducted while demonstrating control parameters for chlorine feed rate and scrubber performance as identified in Table 7-1. Table 7-1 summarizes the MACT control parameters related to HCl and Cl_2 emissions. As suggested by the information in Table 7-1, HCl and Cl_2 emissions from hazardous waste combustors are primarily dependent on chlorine feed rates and air pollution control efficiency for acid gases (wet or dry scrubbing). For cement kilns, some dry scrubbing may occur within the process because of the highly alkaline limestone used in the manufacture of cement. Additional information regarding the control parameters and their influence on HCl and Cl_2 emissions is available in other documents (EPA 1992b, 1999d, 1999e) and is not discussed at length here. The MACT control parameters encompass the key control parameters influencing HCl and Cl_2 emissions, and are similar to BIF control parameters. However, the MACT parameters have been reviewed more recently against an extensive emissions database.

The purpose of summarizing the MACT control parameters in Table 7-1 is not to suggest that MACT emission standards should necessarily be imposed within the context of risk-based permitting, or to imply that any facility will be required to achieve early compliance with MACT emissions standards. Rather, the

purpose of reviewing the MACT control parameters in this guidance is to identify the feed and operating conditions that influence HCl and Cl_2 emissions, as well as to highlight the controls which will be implemented at most hazardous waste combustors in accordance with the requirements of the MACT rule. To the extent that risks from HCl and Cl_2 emissions are already adequately controlled by regulatory limits on key control parameters, then fewer site-specific risk-based limits may be needed in the RCRA permit. However, if regulatory controls are not applicable or sufficiently comprehensive, then additional site-specific risk-based limits may be warranted to ensure protection of human health and the environment.

Risk-based limits for chlorine feed rates, scrubber parameters, and maximum HCl and Cl_2 emission rates may be established in the RCRA permit based on the risk burn and risk assessment as necessary for protection of human health and the environment. Alternatively, the permit writer may determine that limits imposed pursuant to MACT or other regulatory provisions are sufficient. Fewer permit limitations based on the risk burn may be necessary when the risk burn can be performed in conjunction with a RCRA trial burn or MACT performance test. A greater number of risk-based permit limitations may be necessary when the risk burn and RCRA or MACT performance tests reflect different operating modes.

TABLE 7-1

MACT CONTROL PARAMETERS ASSOCIATED WITH HYDROGEN CHLORIDE AND CHLORINE EMISSIONS

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
Chlorine Feed Rate	Maximum total chlorine (organic and inorganic) feed rate in all feed streams [1]	Comprehensive performance test	12 hour	Average of the test run averages	
Wet Scrubbers High Energy: - venturi - hydrosonic - collision - free jet Low Energy: - spray tower - packed bed - tray tower	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	High energy scrubbers: minimum pressure drop across scrubber	Comprehensive performance test	1 hour	Average of the test run averages	
	Low energy scrubbers: minimum pressure drop across scrubber	Manufacturer specifications	1 hour	N/A	
	Low energy scrubbers: minimum liquid feed pressure	Manufacturer specifications	1 hour	N/A	
	Minimum liquid pH	Comprehensive performance test	1 hour	Average of the test run averages	
	Minimum liquid scrubber flow rate and maximum flue gas flow rate or minimum liquid/gas ratio	Comprehensive performance test	1 hour	Average of the test run averages	

TABLE 7-1

MACT CONTROL PARAMETERS ASSOCIATED WITH HYDROGEN CHLORIDE AND CHLORINE EMISSIONS (continued)

	Control Parameter	Limits From	Averaging Period	How Limit Is Established	Other Considerations
Dry Scrubber	Maximum flue gas flow rate or kiln production rate	Comprehensive performance test	1 hour	Average of the maximum hourly rolling averages for each run	
	Minimum sorbent feed rate	Comprehensive performance test	1 hour	Average of the test run averages	
	Minimum carrier fluid flow rate or nozzle pressure drop	Manufacturer specifications	1 hour	N/A	
	Identification of sorbent brand and type or adsorption properties	Comprehensive performance test	N/A	Same properties based on manufacturer specifications	

Notes: ESP = electrostatic precipitator   MACT = maximum achievable control technology
        IWS = ionizing wet scrubber   N/A = not applicable

[1] = This limit applies to all feed streams except natural gas, process air, and feed streams from vapor recovery systems, provided that expected levels of constituents in those feed streams are accounted for in documenting compliance with feed rate limits. See the MACT rule preamble (EPA 1999c) for further information.

7.2   PARTICLE-SIZE DISTRIBUTION

Information on particle-size distribution and particle density are recommended for the air dispersion and deposition modeling that supports risk assessments (EPA 1998a and 1999b). Particle size and particle density directly affect particle terminal velocity. Large particles fall more rapidly than small particles and are more easily removed from the atmosphere by precipitation. Smaller particles have lower terminal velocities, and very small particles remain suspended in the air flow (EPA 1998a). For site-specific risk assessments, EPA OSW has recommended that most metals and a few organics with very low volatility be assumed to occur only in the particle phase (EPA 1998a). EPA OSW has recommended that mercury and more volatile organics be assumed to partition between the particle and vapor phases. Very volatile organics are modeled only in the vapor phase (EPA 1998a).

Because particle dispersion and deposition are directly related to particle size, predicted ambient impacts and associated risks are also highly dependent on particle-size distribution. A particle-size distribution that is more heavily weighted towards larger particles will result in higher deposition near the source, and reduced air concentration and deposition further away from the source. A particle-size distribution that is more heavily weighted towards smaller particles will decrease deposition near the source, and increase air concentrations and deposition away from the source. In general (but not necessarily in every case), higher deposition near the source is expected to result in higher risks. However, the relationship between deposition and risk will vary, depending on the size of the site and the location of potential receptors relative to maximum deposition. In an air model sensitivity analysis (The Air Group 1997), the particle-size distribution element was found to be a "moderately" sensitive parameter on a scale of "none" to "severe" sensitivity. Moderate sensitivity meant that site-specific data could result in variations in the model outputs of up to 50 percent from default assumptions.

In many cases, the APCD equipment is the primary determinant of particle size and total particle mass emitted from hazardous waste combustion facilities. Advances in air pollution control technology have led to improvements in particulate removal efficiency. Removal efficiencies typically decrease as particle size decreases (i.e., smaller particles are more difficult to remove). According to the proposed MACT rule (EPA 1996a), cyclone separators have typical removal efficiencies of less than 20 percent for particles less than 1

micron in diameter, and about 5 percent for particles less than 0.5 microns in diameter. Fabric filters are

extremely efficient and have reported removal efficiencies of 99 to 99.99 percent for particles as low as 0.1

micron in diameter. ESPs are less efficient at capturing particles in the 0.1 to 1.0 micron range and have

reported removal efficiencies of 90 to 95 percent (EPA 1999f). Based on these observations, a well-operated

APCD greatly decreases the potential mass and mean particle size emitted from combustion facilities.

Some hazardous waste combustion facilities are not equipped with APCD devices. For these facilities,

particle-size distribution is driven strictly by combustor design, feed composition, combustion quality, and

flue gas cooling profile. In a comparison of particle-size distributions for two different types of combustion

equipment, Linak found significantly different distributions (Linak and others 1999) . A laboratory scale

refractory-lined combustor, which was shown to simulate the combustion conditions of a large utility residual

oil fired boiler with respect to particulate emissions, produced very fine particulate with a mean diameter

around 0.1 micron. Conversely, a pilot scale fire-tube package boiler produced a small fraction

(approximately 0.2 percent) of mass with particle diameters less than 0.1 micron, and a very large fraction

(approximately 99.8 percent) of the mass with particle diameters between 0.5 and 100 microns. The larger

particles were shown to be porous, carbonaceous cenospheres resulting from poor carbon burnout.

7.2.1   Model Inputs

Particle-size inputs to the air dispersion and deposition model include: 1) particle density; 2) mass

distribution by particle-size category; and 3) surface area distribution by particle-size category. A minimum

of three particle-size categories (>10 microns, 2-10 microns, and <2 microns) are recommended (EPA

1998a). Because so many variables influence particle-size distribution, a representative distribution is very

difficult to predict. Therefore, the EPA OSW risk assessment guidance (EPA 1998a) has recommended that

existing facilities perform site-specific measurements to determine particle density and particle-size

distribution. Particle density and particle-size distribution measurements are discussed in Appendix B.

Detailed procedures for calculating mean particle diameters and mass and surface area distributions from

stack measurements are discussed in the EPA OSW risk assessment guidance (EPA 1998a). When measured

mass is below the detection limit, it may be appropriate to use a mean particle-size diameter of 1.0 microns in

the model to represent all particle mass (EPA 1998a). The use of a 1.0 micron particle-size results in the particles behaving similar to a vapor in the air model.

7.2.2   Test Conditions for Measuring Particle-Size Distribution

EPA OSW recommends that particle-size data generally be collected under normal operating conditions where ash spiking is not performed. Ash spiking will bias the particle-size distribution and is not likely to be representative of ongoing emissions in terms of particle size.

In lieu of sampling during normal operating conditions, a facility may prefer to measure particle-size distribution during the worst-case test conditions (when these tests do not involve ash spiking). In this case, EPA OSW recommends that the particle-size distribution measurement generally be performed during both the high temperature and low temperature operating extremes. Finer particles are likely to result from higher combustion temperatures, good combustion conditions, and rapid flue gas cooling profiles. Larger particles may be associated with poorer combustion situations or slower flue gas cooling profiles (such as through a heat exchanger or waste heat boiler). Testing during both the high temperature and low temperature operating extremes will allow potential variations in particle-size distribution to be determined and subsequently reflected in the air modeling.

Finally, soot blowing practices at a boiler may affect particle-size distribution. Normal soot blowing practices should generally be determined from the facility's operating record and reflected during one run of the particle-size determination. To the extent possible, EPA OSW recommends that the timing of the soot blowing and particle-size testing be coordinated so that soot blowing is not over-represented or under-represented in the sample, as compared to the number of hours per day that soot blowing normally occurs.

7.2.3   Alternatives When Site-Specific Measurements Are Not Available

In some cases, a site-specific particle-size distribution measurement will not be available. For example, a proposed new facility that needs to develop a particle-size distribution estimate may decide to use a representative distribution from a similar device as recommended by the EPA OSW risk assessment guidance

(EPA 1998a). Stack measurements from a similar unit equipped with similar APCD are preferred whenever possible. However, in the event that stack data from a similar unit are not available, a facility may explore several options. These include: 1) using literature estimates for similarly equipped facilities, 2) using APCD vendor estimates, or 3) performing multiple air and risk modeling runs to bound the range of potential impacts. Each of these options is discussed further below.

7.2.3.1   Literature Estimates

If a particle-size distribution stack measurement is not available for the actual facility (or for a similar facility), the use of a literature estimate may be considered. The literature estimate should generally match the actual facility as closely as possible with respect to the types of fuels and wastes burned and APCD equipment.

For sources equipped with ESPs or fabric filters, the EPA OSW risk assessment guidance (EPA 1998a) recommends a nine-category particle-size assumption to be used for site-specific risk assessment modeling if a more representative site-specific estimate cannot be obtained. The recommended assumptions are reproduced here as Table 7-2. The assumed particle-size diameters range from less than 0.7 to greater than 15.0 microns, with a mass distribution approximately 48% < 2.5 microns and approximately 82% < 10 microns.   The risk assessment guidance also recommends a value for particle density of 1 gram per cubic centimeter (g/cm^3).

For cement kilns equipped with ESPs or fabric filters, a technical support document to the hazardous waste combustor MACT rule (EPA 1999g) uses a particle-size mass distribution estimate of 50% < 2.5 microns and 85% < 10 microns. This distribution compares favorably with the distribution provided in Table 7-2 for sources equipped with ESPs or fabric filters. The estimate is based on the distributions for Portland cement kilns provided in AP-42 (EPA 1995b) of 45 to 64% < 2.5 microns and 85% < 10 microns, as well as distribution data for three hazardous waste burning cement kilns ranging from 50 to 75% < 2.5 microns and 70 to 90% < 10 microns (EPA 1999g).

Particles from cement kilns may have a higher particle density than the density of 1 gm/cm^3 provided in the

TABLE 7-2

**GENERALIZED PARTICLE-SIZE DISTRIBUTION TO BE USED AS A DEFAULT
IN DEPOSITION MODELING IF SITE-SPECIFIC DATA ARE UNAVAILABLE**

Mean Particle Diameter[a] (μm)	Particle Radius (μm)	Surface Area/Volume (μm)	Fraction of Total Mass[b]	Proportion of Available Surface Area	Fraction of Total Surface Area
>15.0	7.50	0.400	0.128	0.0512	0.0149
12.5	6.25	0.480	0.105	0.0504	0.0146
8.1	4.05	0.741	0.104	0.0771	0.0224
5.5	2.75	1.091	0.073	0.0796	0.0231
3.6	1.80	1.667	0.103	0.1717	0.0499
2.0	1.00	3.000	0.105	0.3150	0.0915
1.1	0.55	5.455	0.082	0.4473	0.1290
0.7	0.40	7.500	0.076	0.5700	0.1656
<0.7	0.40	7.500	0.224	1.6800	0.4880

Notes:
[a]Geometric mean diameter.
[b]The terms mass and weight are used interchangeably when using stack test data.

EPA OSW risk assessment guidance (EPA 1998a). A higher density, for example 2 gm/cm^3, may result in up to 50 percent greater dry deposition near the source (The Air Group 1997). The use of a particle density of 2 gm/cm^3 is based on information from the cement kiln industry. Material Safety Data Sheets for cement kiln dust (http://www.lafargecorp.com) list, among the physical and chemical properties, a specific gravity of 2.6 to 2.8 gm/cm^3. This value is for bulk cement kiln dust stored and shipped from a silo as a product. In actuality, the density of stack dust emissions from a cement kiln will depend on the chemical composition and size distribution, which is also a function of the APCD design and operation. Therefore, site-specific measurements of particle density are preferred.

Some hazardous waste burning incinerators and boilers are equipped with wet scrubbing devices to control acid gas emissions. In a technical support document to the hazardous waste combustor MACT rule (EPA 1999g), EPA estimates mass particle-size distributions for incinerators equipped with wet APCD devices as follows:

    C   Liquid injection units: 95% < 2.5 microns and 100% < 10 microns

    C   Solids units: 70% < 2.5 microns and 90% < 10 microns

These estimates are based on data from two hazardous waste burning incinerators, one equipped with an IWS and one equipped with a wet ESP, as well as limited data from municipal and medical waste incinerators. The liquid injection estimate compares favorably with the estimate available in AP-42 (EPA 1995b) for residual oil burning utility boilers equipped with wet scrubbers (97% < 2.5 microns and 100% < 10 microns).

Some liquid injection incinerators and boilers burning low ash, low halogen wastes may not be equipped with any APCD at all. A particle-size distribution is identified in AP-42 (EPA 1995b) for an uncontrolled utility boiler firing residual oil. This mass distribution is 52% < 2.5 microns and 71 % < 10 microns.

Finally, AP-42 (EPA 1995b) identifies several particle-size distribution estimates for coal-fired boilers. These distributions may be appropriate for hazardous waste burning boilers if coal is routinely co-fired as an auxiliary fuel. Selected distributions are summarized here as follows:

	% Mass < 2.5 microns	% Mass < 10 microns
Bituminous and Sub-bituminous Coal		
Dry bottom boiler w/ ESP	29	67
Dry bottom boiler w/ fabric filter	53	92
Dry bottom boiler w/ scrubber	51	71
Spreader stoker w/ ESP	61	90
Spreader stoker w/ fabric filter	26	60
Anthracite Coal		
Dry bottom boiler w/ fabric filter	32	67

It is important to emphasize that EPA OSW only recommends the use of literature estimates, such as those summarized in this section, if site-specific data is unavailable. As documented by Linak (Linak and others 1999), particle-size distributions can vary significantly from unit to unit, and a site-specific determination is

always preferred.

7.2.3.2   APCD Vendor Estimates

In some cases, a facility may be able to obtain particle-size distribution data from the APCD vendor if site-specific data are not available. For example, vendor data for sources equipped with HEPA filters may be sufficient for estimating mass distributions within the three particle-size categories (>10 microns, 2-10 microns, and <2 microns) because 100% of the particle mass would be expected to be below 2 microns in diameter downstream of a HEPA filter.

7.2.3.3   Multiple Modeling Runs to Bound Potential Impacts

Another option when site-specific particle-size distribution data are not available is to perform multiple air and risk modeling runs, using a range of assumed size distributions, to bound the range of potential impacts. For this option, EPA OSW recommends that three different size distributions be modeled to determine the highest impacts for site-specific receptors considering all exposure pathways:

- C   100% mass at 1 micron in diameter;
- C   100% mass at 5 to 7.5 microns in diameter;
- C   100% mass at 12 to 15 microns in diameter.

This approach may be very resource-intensive, but should assure that predicted impacts are conservatively bounded by the risk assessment in the absence of site-specific particle-size data.

CHAPTER 8

DATA ANALYSIS

Once the risk burn has been completed and emissions data are available, the data can be analyzed and the risk assessment can be performed. This chapter (Section 8.1) discusses consolidation of the emissions data from each risk burn test condition prior to evaluation in the risk assessment. This chapter (Section 8.2) also identifies various emissions scenarios that may be evaluated in the risk assessment. Since a risk burn can involve multiple test conditions, EPA OSW recommends that the permit writer and facility give early consideration to how the data from more than one test condition will be combined for subsequent evaluation. In addition, EPA OSW recommends that the permit writer and facility consider whether the risk burn data will be evaluated in conjunction with emissions estimates that may be based on information other than the risk burn (for example, emissions corresponding to an applicable regulatory standard).

8.1   DATA REDUCTION AND COPC SELECTION

A large amount of data will be generated during the risk burn, and these data will need to be reduced prior to evaluation in the risk assessment. Consolidation of data for each risk burn test condition, including treatment of non-detects, is discussed in Section 8.1.1. Section 8.1.2 explains how constituents which are not detected in any test run are addressed in the COPC selection process.

8.1.1   Data Reporting and Treatment of Non-Detects

Consolidation of risk burn emissions data prior to evaluation in a risk assessment is a multi-step process. First, analytical results for the various fractions of a stack gas sampling train are summed to determine a train total. A train total is reported for each constituent and each test run. Eventually, the reported results for three test runs are consolidated to arrive at a test condition total. At several points in the process, questions arise regarding how to treat non-detects. The EPA OSW risk assessment guidance (EPA 1998a)

provides a recommended procedure, and portions of that procedure are repeated here for the convenience of the reader.

Detection limits are defined a number of ways, and terms are not always consistently applied. For the purpose of combustion risk assessments, the EPA OSW risk assessment guidance (EPA 1998a) recommends that the following be reported when constituents are not detected in a stack gas emissions sample:

> ***Reliable detection limits (RDLs):*** RDLs should generally be reported when constituents are analyzed with non-isotope dilution methods, such as the methods for volatile and semivolatile organics, and are not detected. The RDL is a total of 8 standard deviations above the Method Detection Limit (MDL) developmental test data, where the MDL is determined from analysis of at least seven replicate samples of a given matrix in accordance with 40 CFR Part 136, Appendix B. The reported RDL should be adjusted, as appropriate, to account for sample-specific volumetric treatments (e.g., splits and dilutions) that differ from those utilized in the Part 136 MDL determination.

> ***Estimated detection limits (EDLs):*** EDLs should generally be reported when constituents are analyzed with isotope dilution methods, such as the method for D/Fs, and are not detected. EDLs are defined by the individual SW-846 (EPA 1996b) test method, such as Method 8290 for D/Fs, and represent an estimate by the laboratory of the concentration of a given analyte necessary to produce a signal with a peak height of at least 2.5 times the background signal level.

EPA OSW recommends that a facility inform the laboratory of these reporting conventions prior to development of the risk burn QAPP and analysis of the risk burn samples. In particular, MDLs are specific to each laboratory, and some laboratories may not have pre-determined MDLs for all compounds that are quantifiable by a particular method. MDLs determined per 40 CFR Part 136 may need to be explicitly requested for all chemicals to be analyzed and subsequently reported in the risk burn report.

EPA OSW also recommends that a facility provide clear direction to the laboratory regarding how to report a total sampling train mass for each constituent and each run if a constituent is not detected in certain of the analytical determinations. For most of the stack gas sampling trains, separate analyses are performed on various train fractions (for example, a resin fraction and a condensate fraction). The MDLs (and therefore the RDLs) are matrix-specific (i.e., separate MDLs are determined for the resin fraction and the condensate fraction). For data reporting to support site-specific risk assessments at combustion facilities, the following reporting convention is recommended when the results from each sampling train fraction have to be summed

to arrive at a total train mass:

- C If results for all fractions are non-detect, then the full RDLs (or EDLs) should be summed and the result reported with a "less than" sign;

- C If a constituent is detected in some of the train fractions but not in others, then the data should be reported as a range (i.e., "greater than" the total detected amount, but "less than" the total detected amount plus the full RDLs or EDLs for the non-detects). For D/Fs, Method 0023A specifically allows a non-detect to be treated as zero if it is less than 10 percent of the total detected amount, subject to approval by the regulatory agency.

Blank results can also affect whether or not a constituent is considered to be detected. Blanks are not addressed here, but are discussed in detail in Appendix B.

For D/F analysis by Method 8290, there is also the issue of how to report ***estimated maximum possible concentrations (EMPCs)***. An EMPC is characterized by a response with a signal to noise ratio of at least 2.5 for both quantitation ions that meets all the relevant identification criteria except ion abundance ratio. For an EMPC, the ion abundance ratio and quantitative ion signal may be affected by co-eluting interferences. Therefore, an EMPC is a worst-case estimate of the concentration. The EPA OSW risk assessment guidance (EPA 1998a) recommends that EMPCs be treated as full detections in the risk assessment, and encourages application of techniques to minimize EMPCs.

8.1.2 COPC Selection and Treatment of Non-Detects

As discussed in Section 8.1.1, EPA OSW recommends that non-detects be fully carried through the risk burn data reporting process. However, this does not necessarily mean that all non-detected constituents will be evaluated in the risk assessment. Once the data is reported, decisions are needed as to whether the non-detected constituents will be retained as COPCs for the risk assessment. The EPA OSW risk assessment guidance (EPA 1998a) recommends a logical process for making these decisions, and portions of that process are repeated here for the convenience of the reader.

EPA OSW has recommended that constituents that are not detected in the stack emissions during any test run be re-evaluated for inclusion in the risk assessment using the final COPC selection process and flowchart

found in the EPA OSW risk assessment guidance (EPA 1998a). A compound may be excluded from the COPC list if: 1) it is not present in the waste being burned, and 2) it does not have a high potential to be emitted as a PIC, and 3) it has no potential of being emitted and is not of concern due to other site-specific factors (such as background concentrations and community or regulatory concern) (EPA 1998a). Based on this COPC selection process, some constituents that are not detected during any of the test runs and which meet the specified criteria will be eliminated from further consideration in the risk assessment.

In the COPC selection process, EPA OSW recommends that care be taken not to eliminate non-detected constituents that may be limited quantitatively in the final permit, because compliance with an emission rate limit of zero cannot be determined. Quantitative emission limits for certain toxic and bioaccumulative constituents may be established in the final permit to ensure that emissions of those constituents do not exceed the levels which were evaluated in the risk assessment and found not to pose a significant risk to human health and the environment. Constituents which may be candidates for risk-based emission limits in the final permit include D/Fs, specific metals, HCl and Cl_2, and significant waste constituents (for example, chemical warfare agents). Although emission limits for individual organics other than D/Fs may not be routinely established, the permit writer may limit other organic contaminants that are found to be risk drivers, as appropriate.

At the conclusion of the COPC selection process, the constituents retained as COPCs will include: 1) constituents detected in at least one run of the risk burn, 2) constituents which are not detected during the risk burn, but which cannot be excluded as COPCs because they have the potential to be emitted or are otherwise of concern, and 3) constituents which may be limited by quantitative emission rates in the final RCRA permit. For constituents which are not detected but are retained as COPCs, EPA OSW has recommended that the full RDL or EDL generally be used in calculating an emission rate for each run and each test condition for subsequent evaluation in the risk assessment (EPA 1998a).

The final step in the risk burn data consolidation process is calculation of a test condition emission rate from the three test runs. For each test condition, EPA OSW has recommended that the emission rate for each constituent be calculated as the 95th percentile of the arithmetic test mean, or the maximum value from the three test runs, whichever is lower (EPA 1998a). The EPA OSW risk assessment guidance (EPA 1998a and

1999b) recommends that emissions data from the risk burn be evaluated in a site-specific risk assessment to provide reasonable maximum exposure (RME) estimates of potential risks to human and ecological receptors. Results from probabilistic risk assessments show that setting as few as two factors at RME levels or high end (e.g., near the 90th percentile) while the remaining variables are set at less conservative, typical or "central tendency" values (e.g., near the 50th percentile) results in a product of all input variables at an RME level (e.g., 99th percentile value) (EPA 1998a). The EPA OSW risk assessment guidance identifies risk burn emissions data as one of the variables that is recommended to be set at the RME level.

8.2   EMISSION SCENARIOS TO BE EVALUATED FOR RISK

Once the risk burn data have been consolidated for each test condition and COPCs have been selected as discussed in Section 8.1, the risk assessment can be performed   When a risk burn involves multiple test conditions, the permit writer and facility will need to decide whether the data from each test condition should be evaluated separately, or whether the data will be combined in some manner. In addition, decisions will be needed regarding evaluation of emissions beyond those measured during the risk burn. For example, a facility may prefer to evaluate risks associated with emissions at a regulatory standard or with an emissions estimate (i.e., zero SRE) in the risk assessment. This section identifies various emissions combinations that may be evaluated for risk.

Consolidation of data from multiple test conditions can encompass a range of options, depending on how the test conditions are structured and how the data will be presented for the risk management decision. EPA OSW recommends that these options be considered carefully prior to establishing test conditions and subsequent data collection. As discussed in Chapter 3, EPA OSW recommends that the emissions scenarios to be evaluated in the risk assessment be clearly identified in the risk burn plan, and that the test plan also indicate whether the risk assessment will consider emissions estimates based on information other than the risk burn.

Possible emissions scenarios to be evaluated for risk include: 1) calculation of risk ranges corresponding to specific test conditions (e.g., DRE and SRE); 2) consolidation of the highest emissions data from multiple test conditions for calculation of a single high-end risk value; 3) combining test data with emission rate

estimates; 4) combining test data with regulatory standards; 5) combining test data with emission rate estimates for abated and unabated fugitive emissions and emission rate estimates for expected chemicals that could not be incorporated into the test (i.e., due to lack of validated stack sampling methods, lack of available waste quantities for the test, or an inability to represent waste diversity during the test); or 6) any combination. Unless complete emissions determinations (for D/Fs, other organics, metals, and HCl/Cl$_2$) are conducted during every test condition, then consolidation of data from multiple conditions will need to be considered. Examples of possible emission scenarios to be evaluated for risk are provided below and in Appendix A.

Calculation of Risk Ranges Corresponding to Specific Test Conditions

A facility may choose to collect risk burn emissions data in conjunction with both the DRE and SRE tests. The DRE and SRE tests typically bound the operating extremes of the combustion unit by representing the lowest and highest combustion temperatures, as well as worst-case feed and APCD conditions. If complete risk burn emissions data (D/Fs, other organics, metals, HCl/Cl$_2$, and particle size information) are collected during both test conditions, then the facility may prefer to evaluate the emissions data set from each test condition separately in a site-specific risk assessment to calculate risks corresponding to each end of the operating envelope.

Consolidation of Multiple Tests for Calculation of a Single High-End Risk Value

It is more likely that the facility described above would not sample for metals during the DRE test, perhaps to limit metals spiking. In this case, complete data for all COPCs would not be available for both test conditions, and the risk burn data would need to be consolidated to complete the site-specific risk assessment. One option might involve combining the metals emissions from the SRE test with the *higher* of the D/F and organic emissions from either the SRE or DRE tests to calculate a single RME risk estimate.

Combining Test Data with Emissions Estimates

For either of the above approaches, the facility may have preferred to estimate maximum mercury emissions

by assuming zero SRE at a maximum mercury feed rate instead of spiking mercury during the SRE test. This maximum mercury emissions estimate could be combined with the measured emissions data for calculation of either a risk range or a single risk estimate.

Combining Test Data with Regulatory Standards

Finally, the facility described thus far may be planning for future compliance with the hazardous waste combustor MACT standards. The facility may have determined that physical modifications to the combustion system are not needed, but plans to reduce the feed rate of certain metals to meet the MACT standards. The facility may decide to evaluate an extra scenario in the site-specific risk assessment to reflect post-MACT operation. In this scenario, the MACT emission rate limits for D/Fs, metals, and HCl/Cl_2 might be evaluated in the risk assessment, together with emissions data for the non-MACT metals collected during the SRE test condition and the non-D/F organic emissions data from the DRE test condition of the risk burn.

Obviously, if a facility collects emissions data under additional test conditions, then the data management and analysis options become more complex. As explained in Chapter 3, EPA OSW recommends early communication and coordination between the permit writer and facility.

Finally, EPA OSW recommends that recent EPA direction in characterizing and communicating risk (EPA 1995c) to the public be considered. The *Guidance for Risk Characterization* (EPA 1995c) recommends that risk assessments include risks based on data reflecting both RME and central tendency (average) conditions. As appropriate, site-specific risk assessments may be completed based on both RME and average emissions data. This could assist in the risk communication process by allowing the facility and EPA to discuss a broader risk range with the public and to consider effects of variations in operating conditions on potential risks. However, RME conditions are generally expected to form the basis of permit conditions.

CHAPTER 9

RISK-BASED PERMIT CONDITIONS

After the site-specific risk assessment is performed and results are available, a final decision can be made regarding inclusion of risk-based conditions in the RCRA permit. The final RCRA permit represents an important and integral conclusion to the risk-based permitting process. The final permit identifies the operational conditions that are necessary to protect human health and the environment, and how that will be assured on an ongoing basis. This chapter concludes the ongoing dialogue provided throughout this document regarding potential risk-based permit terms.

Risk-based permit terms may be appropriate when emissions are projected to present a significant risk to human health and the environment. The EPA OSW risk assessment guidance (EPA 1998a) recommends several options when a risk assessment indicates potentially significant risks, and these options are repeated here for the convenience of the reader:

- C   Collecting additional site-specific information that is more representative of the exposure setting and performing additional iterations of the risk assessment based on the new information;

- C   Establishing permit terms (for example, waste feed limitations, process operating conditions, or environmental monitoring) to limit operations and performing additional iterations of the risk assessment to demonstrate that the resulting emissions are protective of human health and the environment;

- C   Denying the permit, if the initial risk assessment or subsequent iterations indicate potentially unacceptable risks.

However, even if the risk assessment indicates that projected risks will not be significant, risk-based permit terms may still be necessary to protect human health and the environment by ensuring that emissions remain below the levels which were measured during the risk burn and found to be protective. The risk burn and risk

assessment are typically based on assumptions that include:

     C   Waste composition, physical form, and feed rates, with key considerations outlined in Chapters 4-7;

     C   Operating conditions and parameters, including those related to combustion conditions (temperature, turbulence, and residence time) and APCD operation (pressure drops, flow rates, liquid-to-gas ratios, inlet temperatures, and power) as identified in Chapters 4-7;

     C   Emission rates associated with specific feed and operating conditions.

Within the bounds of the conditions demonstrated during the risk burn, emissions are characterized and evaluated in the risk assessment to determine whether they may present a significant risk to human health and the environment. Outside of those bounds (unless additional information is available), emissions and risks are generally unknown. Therefore, in order to protect human health and the environment, it may be necessary to limit operations to prevent higher emissions than those represented by the risk burn and risk assessment.

Site-specific factors will inform a decision regarding the need for, as well as the extent of, any risk-based RCRA permit limits to assure that ongoing emissions do not present a significant risk to human health and the environment. Key factors generally include, but are not necessarily limited to: 1) the emissions scenarios evaluated in risk assessment; 2) the feed and operating scenarios demonstrated during the risk burn; 3) whether key feed and control parameters are already limited by another permit or regulatory mechanism; 4) facility-specific operating practices; and 5) the potential for emissions to pose significant risks to human health and the environment.

As discussed in Chapter 3, few (if any) risk-based permit limitations may be necessary when the risk burn can be combined with a RCRA or MACT performance test, and when emissions and key control parameters are already sufficiently addressed by regulatory limits. A greater number of permit limitations may be necessary when the risk burn and performance tests reflect different operating modes, or when emissions and key control parameters are not limited by another mechanism. EPA OSW recommends that expectations regarding risk-based permit terms be clearly articulated in the risk burn plan, as discussed in Section 3.5.

The potential for emissions to pose significant risks to human health and the environment is an important

consideration in determining appropriate permit terms. If the potential risks associated with all foreseeable operating modes and operating extremes are insignificant, it may be appropriate for the permit writer to conclude that risk-based permit conditions are not necessary to protect human health and the environment, and to simply document the basis for the risk assessment emissions assumptions in the administrative record. In some cases, it may be appropriate for the permit writer to incorporate general monitoring and reporting provisions into the final permit to protect human health and the environment by ensuring that significant changes that could affect emissions (including types of wastes treated or major changes to operating parameters) are reported to EPA or the appropriate state agency. When potential risks are more significant, a permit writer may conclude that specific permit limits are necessary to protect human health and the environment. As identified in Chapter 3, risk-based permit terms may take the form of emission limits and specifications for periodic stack testing, restrictions on feed or operating control parameters and associated monitoring provisions, or some combination.

In summary, the emission rates (and related feed and operating conditions) that are demonstrated during the risk burn and evaluated in the risk assessment should clearly correspond to potential permit terms and conditions. The permit terms can ensure protection of human health and the environment by prohibiting operations outside of the operating boundaries represented by a risk burn and risk assessment that demonstrates emissions will not pose a significant risk. When a permit decision involves the use of a site-specific risk assessment, final RCRA permit terms will ultimately depend on the operating practices, emission levels, and risk results specific to each facility, and the permit writer should work closely with the facility to determine appropriate conditions for the risk burn and a corresponding permit approach. Illustrations are provided in Appendix A.

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