REGION 5

Risk Assessment for the Waste Technologies Industries (WTI) Hazardous Waste Incinerator Facility (East Liverpool, Ohio)

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Volume III:
CHARACTERIZATION OF THE NATURE AND MAGNITUDE OF EMISSIONS

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C O N T E N T S

C O N T E N T S (continued)

T A B L E S

C O N T E N T S (continued)

I. INTRODUCTION

A. Overview of Routine Emissions

An initial step of the WTI human health and ecological risk assessments is to evaluate the nature and magnitude of atmospheric emissions during operations of the WTI facility. This involves identifying potential emission sources, characterizing the composition of emissions from these sources, and developing emission rates for the substances of potential concern from each significant source.

Routine operations at the WTI facility will result in emissions from several locations within the facility, including particles and vapors in stack gases generated by the incinerator, fugitive organic vapors emitted during waste processing and storage, and particles released during handling of ash produced by incineration. The general approach used to characterize routine emissions associated with these sources during normal operations is described in this volume, with details provided in Appendix III-1. The characterization of potential emissions during on-site and off-site accidents is described in Volume VII.

Normal combustion processes in hazardous waste incinerators will result in the release of stack gas emissions into the atmosphere. These emissions will consist primarily of combustion gases, such as carbon dioxide (CO_2), carbon monoxide (CO), water, nitrogen, and oxygen. However, despite the high temperatures typical of hazardous waste incinerators, a fraction of the organic compounds in the waste feed can still pass through the incineration process without being combusted. In addition to the uncombusted residues of the waste feed, fragments of the partially combusted organics from the feed may be emitted along with organic chemicals formed through reactions in the combustion or post-combustion zones. These compounds, known as products of incomplete combustion (PICs), can be different in chemical structure from the original organic compounds in the waste feed. Other potentially hazardous substances, such as metals, may also be present in the stack emissions.

In the risk assessment, substances of potential concern in the stack gases are classified as follows:

- Polychlorinated dioxins and furans (PCDDs/PCDFs), which are believed to be a product of incomplete combustion of some types of hazardous waste;

- Other organic chemicals, including PICs other than PCDDs/PCDFs, and residues of organic chemicals present in the feed that are not completely combusted within the incinerator;

- Metals, which may be present in the waste but can not be destroyed by combustion;

- Acid Gases, such as nitrogen oxides (NO_x), sulfur oxides (SO_x), and hydrogen chloride (HCl), which are formed during the combustion process; and

- Particles, which may be entrained in the stack gas during waste combustion, or formed as stack gases cool in the post-combustion zone of the incinerator.

Comprehensive stack testing, including the collection of several sets of data on PCDD/PCDF emission rates, was performed at the WTI facility to provide site-specific estimates of organic emissions. For the risk assessment, these site-specific measurements are supplemented by developing a waste feed chemical composition profile (based on wastes received or projected to be received by WTI during its first year of operation) and applying an incinerator destruction and removal efficiency (DRE) (based on testing at the WTI facility) to estimate emissions for chemicals not analyzed for during the stack testing. Particle emissions and acid gas emissions are also estimated based on stack testing at the WTI facility. For metals, data on system removal efficiencies (SREs) derived from testing at the WTI facility are used along with the projected waste feed composition to estimate emissions. Where SRE data from WTI tests are not available, thermodynamic considerations of metal behavior are used to extrapolate from metals for which test data are available to other metals that were not analyzed for at WTI. In this manner, through a combination of testing and predictive modeling, incinerator stack gas emission rate estimates are developed for the risk assessment.

In addition to incinerator stack emissions, atmospheric releases may occur from fugitive sources during waste unloading, processing, and storage, and during the handling of incinerator ash. The following potentially significant sources of fugitive organic vapor emissions have been identified through an analysis of the WTI facility design and operating procedures and a review of the operating experience at similar incineration facilities:

1) Carbon adsorption bed (CAB) system, which controls emissions from tanks in the organic waste tank farm building and from the container processing area;

2) Seals, valves, and flanges associated with tanks and piping in the organic waste tank farm building that are vented from the building;

3) Wastewater holding tank; and

4) On-site truck wash station.

In addition to these sources of organic vapor emissions, the bag filter used to control particle emissions during the loading of fly ash from the incinerator air pollution control system into trucks is identified as the primary source of fugitive ash handling emissions. Substances of potential concern that may be emitted from these fugitive emission sources are identified through an evaluation of the specific processes resulting in the release, and a review of the waste feed composition profile. Emission rates for fugitive sources are developed using the waste profile information and predictive models.

Process upsets may periodically occur during normal operation of the WTI facility. These upsets may include, but are not limited to: 1) unplanned plant shutdowns, 2) interruptions in control measure systems, 3) interruptions in air flow, and 4) kiln overpressure events. Although brief periods of high emissions may result from these events, the magnitude of emissions from process upsets is not expected to be significant compared to the quantity of routine facility emissions. Chapter V describes the identified process upsets and their relative contributions to total facility emissions.

B. Peer Review Group Comments

As part of the review process for the WTI Risk Assessment Project Plan (U.S. EPA 1993a), a peer review panel provided several recommendations on the identification of chemicals emitted from the WTI facility and the estimation of the magnitude of emissions. Peer Review Panel recommendations that are specifically addressed in the analysis described in this volume include the following:

- Additional Compounds to Be Evaluated - The Peer Review Panel recommended that the Risk Assessment should include several constituents not identified in the Project Plan, including polycyclic aromatic hydrocarbons (PAHs) and two additional metals: copper and aluminum.

- Characterization of Organic Chemical Emissions - The Peer Review Panel recommended that additional, more comprehensive stack testing be performed at the WTI facility to provide site-specific organic emission estimates. In addition, it recommended that a waste feed chemical composition profile be developed and an incinerator destruction and removal efficiency (based on testing at the WTI facility) be applied to estimate emission rates for individual chemicals in the waste feed that were not measured directly in the stack testing.

- <u>Characterization of Dioxin/Furan Emissions</u> - The Peer Review Panel recommended that additional data on dioxins and furan emission rates be collected at the WTI facility to provide site-specific data over an extended time period.

- <u>Development of Metal Emission Rates</u> - The Peer Review Panel recommended that the existing data derived from the trial burns be used along with thermodynamic considerations of metal behavior to extrapolate the testing results to other metals that were not tested at WTI.

- <u>Consideration of Fugitive Emissions Sources</u> - The Peer Review Panel recommended that an evaluation of fugitive emissions at the WTI facility from sources other than the incinerator stack be conducted.

- <u>Uncertainty of Emission Rates</u> - Several members of the Peer Review Panel emphasized the need for a comprehensive evaluation of uncertainty with respect to emission rate estimations, and recommended the incorporation of sensitivity analyses of the modeling results and the selection of input parameter values.

The manner in which these comments are addressed is described in the following sections of this volume.

II. DATA USED IN
CHARACTERIZING EMISSIONS

A. Waste Profile Data

Wastes arrive at the WTI facility in a variety of forms (e.g., bulk, drummed) and physical states (e.g., liquids, solids, and sludges). Each type of waste that is incinerated can affect incinerator stack emissions. Pumpable wastes typically have the highest volatile content, and thus represent the most significant source of fugitive vapor emissions. Although a list of specific substances in the pumpable and non-pumpable wastes handled by the facility is not maintained by WTI, the facility does require waste profile sheets for each waste stream, which indicate the physical form and chemical content of each waste stream routinely handled at the facility.

To identify specific substances likely to be in the wastes handled by the facility, a data base has been developed from projections based on the information in the waste profile sheets provided by WTI (see Chapter II of Appendix III-1 for a more complete discussion). These profiles are completed by the generator prior to a waste being received by WTI to document the expected composition of the waste and to receive acceptance from WTI. The profiles include the following information:

- Waste composition (within expected ranges);
- Physical state ("liquid", "liquid, solid/liquid mix", "solid", "solid/liquid mix", "solid, solid/liquid mix");
- Specific handling instructions;
- Hazardous waste codes;
- Anticipated annual volume; and
- Approximate concentrations for a list of specific analytes tested by the generators. These analytes include metals, certain anions (e.g., chloride, fluoride, and bromide), and certain organics (e.g., PCBs, dichlorofluoromethane, and trichlorofluoromethane).

Prior to approving a waste for acceptance, WTI reviews the data in the profile and verifies they are within permit conditions and other operating constraints. Once a waste is accepted by WTI, the profiles must be maintained by WTI, and checked against manifests as wastes

are shipped to the facility. In addition, "fingerprint" analyses are performed by WTI at the time of waste receipt to verify that the waste is consistent with the waste profile.

To develop estimated annual average chemical concentrations for the overall waste stream received by the WTI facility, information from 78 waste profile sheets is coded into a data base (to protect confidentiality), and individual waste streams are then ranked based on projected total annual volume. These 78 profile sheets provide information on the wastes actually received at WTI during the first nine months of operation, and are used along with waste profile receipt data to develop a list of wastes to be received at the WTI facility.

In estimating annual average concentrations in the overall waste stream, projected quantities for individual waste streams are derived from the waste profile sheets. Individual waste streams that each comprise less than 0.5 percent of the total volume are deleted from the data base. The deleted waste streams constitute 4.45 percent of the total waste projected to be received by the WTI facility, leaving 95.55 percent of the total waste stream in the data base.

Data on volumes of individual waste streams actually received during the first nine months of operation at the WTI facility are also compared against the projections contained in the waste profile sheets. As would be expected, there is considerable variability between the projected volumes for individual waste streams and the actual volumes received. For many waste streams, the projected volumes differ from the actual volumes by more than a factor of 10, and in several cases the difference is more than a factor of 100. However, when evaluated over the course of a year the projections appear to provide a reasonable estimate of the overall waste feed. For example, the projected volumes for the top 10% of the individual waste streams (i.e., the 8 waste streams with the largest projected volumes) make up approximately 55% of the total projected waste. These 8 streams also make up a large portion (about 40%) of total waste actually received during the first nine months of operation.

The approximate constituent breakdown for each individual waste stream is estimated based on information provided by the generators in the waste profile sheets. Waste stream constituents are generally reported in the waste profile sheets as ranges (e.g., 0 to 30 percent of total waste stream). In the risk assessment, the upper bound of the range for each waste stream constituent is assumed to be a conservative estimate of the constituent content in the waste stream. These upper bound concentration estimates for individual constituents are then summed to characterize the composition of the overall waste stream. Using this methodology, the combined upper bound percentages for individual constituent in the waste usually exceed 100 percent. In such cases, the individual constituent concentrations are normalized to total 100 percent, keeping the relative amounts of each constituent the same as in the waste profile description.

As discussed in detail in Chapter II of Appendix III-1, a number of refinements are in the data base prior to estimating concentrations of specific chemicals in the facility waste streams. These refinements include:

- Eliminating chemicals that can not be adequately characterized, including a compound listed as "2,3-dibromophosphate" and a compound listed under a confidential trade name that can not be identified. Such chemicals represent less than 1% of the volume of waste stream in the data base.

- Eliminating "ash" for which a specific composition can not be estimated and which should be removed by ash handling systems. Ash constitutes approximately 5% of the waste volume.

- Eliminating "miscellaneous" substances such as "grit", "dirt", "rust", "trash", "tyvek", and "absorbent", which are not expected to contribute to facility emissions, and can not be adequately characterized. "Miscellaneous" substances represent 3% of the volume of the total waste stream.

- Eliminating "lithium batteries", which represent about 1% of the waste, and can not be adequately characterized for the purposes of this risk assessment.

In addition, identical constituents reported under different names are consolidated and reported under one listing, and isomeric compounds (e.g., ortho-, meta- and para- isomers of xylene) are summed and reported under a single listing. Although some waste streams are eliminated from consideration, as noted earlier, the remaining data base of waste streams is prorated to account for full thermal capacity of the unit.

Concentrations of individual constituents in the overall waste data base are adjusted using a "correction factor" calculated using the analytical results for the limited set of metals, anions and other analytes in the waste profile sheets. For example, each waste profile sheet contains analytical results for chloride, as well as concentration ranges for all chemicals in the waste stream that contain chlorine. After the quantities of all chemicals containing chlorine are estimated using the ranges reported by the generators, the corresponding amount of chlorine is compared to the total quantity of chloride indicated in the analytical results presented in the waste profile sheets. A correction factor is then calculated as follows:

$$CF \quad \frac{mol/yr \ of \ Cl, \ analytical \ results}{mol/yr \ of \ Cl, \ generator \ ranges} \qquad \text{(II-1)}$$

Compounds containing chlorine are then multiplied by this factor to ensure consistency with the analytical results. Correction factors for the other specific analytes reported in the waste profile sheets are calculated and applied in the same manner.

Finally, based on physical state descriptions provided by the generators in the waste profile sheets, the waste stream constituent list is divided into five "composite" waste streams: (1) liquid; (2) liquid, solid/liquid mix; (3) solid; (4) solid/liquid mix; and (5) solid, solid/liquid mix. Of these, three categories ("liquids", and "liquid, solid/liquid mix" and "solid/liquid mix") are designated pumpable based on physical characteristics such as viscosity. The remaining two categories ("solid" and "solid, solid/liquid mix") are considered to be non-pumpable.

B. Overview of Stack Testing at the WTI Facility

To the extent possible, testing performed at the WTI facility is used to identify substances of potential concern in the stack gases, and the estimated chemical-specific emission rates. Two major stack emission measurement programs have been performed at the WTI facility under the RCRA permit:

- Trial burns conducted in March 1993 (ENSR 1993) and February 1994 (ENSR 1994a); and

- Incinerator performance tests conducted in August 1993 (WTI 1993), February 1994 (Entropy 1994), April 1994 (ENSR 1994b), August 1994 (ENSR 1994c; ENSR 1994d), and December 1994 (ENSR 1995).

The purpose of the trial burn program was to: (1) demonstrate that the incineration system met permit requirements for organic destruction and removal efficiency (DRE); (2) demonstrate that hydrogen chloride, chlorine, and particle emissions would meet permit requirements while operating under various worst-case operating conditions; (3) establish system removal efficiencies for seven specific metals; and (4) define the range of allowable operating conditions for the incineration system. As with testing performed at similar facilities, the trial burns at the WTI facility utilized engineered waste feeds specifically synthesized to represent reasonable worst-case combustion or emission conditions.

In addition to the trial burns, WTI conducted several performance tests. These performance tests differed from trial burns in that they were conducted while the incinerator was operating under normal conditions and burning routine wastes, rather than synthetic, "engineered" waste streams. Performance tests are believed to be more representative of day-to-day operations, whereas trial burns are meant to evaluate reasonable worst-case conditions.

The original trial burn at the WTI facility was conducted in March 1993. This trial burn consisted of testing at three different incinerator operating conditions, with three test runs performed under each test condition, for a total of nine test runs. All nine test runs were performed using synthetic wastes with the maximum total chlorine feed rate and maximum heat rate (in lower heating value). Specifics of the three test conditions are as follows:

● Condition 1 was designed to establish compliance under high kiln temperature, maximum kiln aqueous waste feed rate, maximum kiln organic liquids feed rate, and maximum toxic/carcinogenic metals feed rate. The results from this test condition were intended to establish system removal efficiencies for toxic and carcinogenic metals, to allow the development of metals feed rate permit limits.

● Condition 2 was designed to establish compliance at low kiln temperature, minimum secondary combustion chamber (SCC) temperature, maximum SCC aqueous liquids feed rate, and maximum pumpable ash feed rate to the kiln.

● Condition 3 was also conducted at low kiln temperature, and was designed to study operation at maximum solids feed rate to the kiln.

In the trial burn, WTI was required to demonstrate a 99.99% destruction and removal efficiency (DRE) for the following principal organic hazardous constituents ("POHCs"): chlorobenzene, trichloroethene, 1,2,4-trichlorobenzene, and carbon tetrachloride. The DRE is defined as:

$$DRE_i = 1 - \frac{Emission\ Rate\ of\ POHC_i}{Feed\ Rate\ of\ POHC_i} \qquad (II-2)$$

During the trial burn, three of these four POHCs were fed during each test run. Carbon tetrachloride and chlorobenzene were fed under each of the three conditions; trichloroethene

was fed under Condition 1 and 2; 1,2,4-trichlorobenzene was fed under Condition 3. In addition, all of the runs for the three conditions included sampling and analysis for PCDD/PCDF and other organic compounds in the stack gas.

The March 1993 trial burn also included the measurement of emissions of seven metals: antimony, arsenic, beryllium, cadmium, chromium, lead, and mercury.[1] Measurements for the seven tested metals were performed only under Condition 1, i.e. the condition intended to maximize metal emissions. Using the emission rates detected during three runs under Condition 1, and the concentrations of metal in waste feed during each run, system removal efficiencies (SREs) were measured for each of the seven metals. The SRE is defined as:

$$SRE_i \quad 1 \quad \frac{Emission\ Rate\ of\ Metal_i}{Feed\ Rate\ of\ Metal_i} \qquad \text{(II-3)}$$

The average SREs measured in the trial burn are presented in Table II-1.

Early in April 1993, WTI representatives notified U.S. EPA that preliminary test results indicated that the required DRE had not been demonstrated for carbon tetrachloride during Condition 2 of the trial burn. U.S. EPA evaluated the test results and determined that the failure had been caused by carbon tetrachloride present in a very dilute aqueous stream fed into the SCC. U.S. EPA subsequently imposed restrictions to ensure that the incineration system would be operated in compliance with the requirements of its permit, including prohibiting aqueous waste feeds to the SCC. In February of 1994, WTI conducted a second trial burn with a revised Condition 2, excluding aqueous waste feed to the SCC. In this second trial burn, all required performance standards were met during revised Condition 2, which consisted of four test runs.

In June 1993, U.S. EPA expressed concern over elevated PCDD/PCDF emission rates recorded during the March 1993 trial burn. In order to reduce the PCDD/PCDF emissions, WTI requested a permit modification to install an enhanced carbon injection system (ECIS). The ECIS injects dry activated carbon into the flue gas stream at two locations, providing a removal mechanism for organic substances through adsorption onto carbon particles. The airborne carbon particles are subsequently removed from the flue gas with the fly ash in the electrostatic precipitator (ESP) component of the air pollution control system. As a condition of approval of the installation of this new system, U.S. EPA required quarterly stack testing

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[1] Stack sampling was not performed for the three other regulated metals — barium, silver, and thallium — based on WTI's agreement to accept permit conditions for these metals assuming no removal by the incineration or emission control system.

for PCDDs/PCDFs and particles for the first year of operation, with annual testing thereafter. These "ECIS performance tests" included a minimum of five test runs, while burning typical wastes with varying total chlorine content. The modified permit required that WTI comply with an average[2] stack gas PCDD/PCDF concentration of 30 ng/dscm (total sum of the tetra-through-octa congeners), a value recommended in U.S. EPA's May 1993 Draft Strategy for the Combustion of Hazardous Waste (U.S. EPA 1993b).

The ECIS was installed at WTI in July 1993. The initial ECIS performance test conducted in August 1993, and all subsequent performance tests and trial burns, demonstrated compliance with the PCDD/PCDF permit limit of 30 ng/dscm. The August 1994 performance test included two extra runs to gain additional data on the potential effects of increased chlorine feed rate on PCDD/PCDF emissions, and the December 1994 performance test consisted of a total of 11 test runs over a range of chlorine feeds and two different kiln temperatures. PCDD/PCDF congeners emission rate measurements used in the Risk Assessment are presented in Appendix III-2, and are summarized in Table II-2.

Both the chlorine feed rate and dioxin/furan emission rate data from the trial burns and August 1994 performance test are presented in Table II-2. As shown in Table II-2, PCDD/PCDF emissions were measured over a range of total chlorine feed rates from approximately 400 lb/hr to 3,300 lb/hr. A slight trend in the dioxin/furan emissions and chlorine feed rate at the WTI facility is suggested based on these data (see Figures II-1 and II-2). However, regression analyses indicate low statistical significance in this trend ($r^2 = 0.084$ for Total Emissions and $r^2 = 0.188$ for TEQ Emissions). Thus, no clear relationship between total chlorine feed rate and PCDD/PCDF emissions is demonstrated.

In addition to PCDD/PCDF, WTI voluntarily conducted stack sampling for an extended list of volatile and semivolatile organic products of incomplete combustion (PICs) during all runs of the August 1994 performance test and nine runs of the December 1994 performance test. In addition to the 17 homologs of PCDD/PCDF, the August 1994 PIC testing included a search for 36 volatile compounds, 52 semivolatile compounds (eight compounds were analyzed by both volatile and semivolatile methods), nine of the 10 categories of PCBs, and four specifically designated pesticides (specific compounds analyzed for in the August 1994 PIC testing are indicated in Appendix III-3). The December 1994 performance test analyzed for the same PICs, plus decachlorobiphenyl, which had not been analyzed for in the August test due to analytical interferences. It should be noted that the original March 1993 trial burn included searching for a list of 24 organic PICs and POHCs, and that stack samples from the February 1994 trial burn were analyzed for 39 volatile PICs and 64 semivolatile PICs.

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[2]   Average over the five runs of the ECIS performance test.

However, since these organics data were collected while burning synthetic trial burn waste instead of real waste, they were deemed less representative than the August 1994 PIC data.

Altogether, the trial burns and performance tests conducted at WTI after installation of the ECIS have yielded 37 test runs of PCDD/PCDF emission data and 16 test runs of PIC data. Because of the timing of this risk assessment, the results of the December 1994 testing can not be evaluated along with the earlier test results. Therefore this risk assessment relies on the 26 PCDD/PCDF test runs and seven comprehensive PIC test runs conducted from August 1993 through August 1994.

C. Key Assumptions for Emissions Characterizations

The key assumptions used in performing emission characterizations for the WTI facility are summarized in Table II-3. This table indicates the basis for the assumptions listed, the estimated relative magnitude of the assumptions' effect on the overall risk assessment, and the direction of the effect, if known. These assumptions are further discussed in Chapter V of this report.

TABLE II-1	
Average System Removal Efficiencies (SREs) Measured at the WTI Facility	
Metal	**SRE (%)**
Antimony	99.986
Arsenic	99.977
Beryllium	>99.991
Cadmium	99.987
Chromium	>99.9993
Lead	99.990
Mercury	6.54
Source: March 1993 trial burn (ENSR 1993), average of three runs.	

TABLE II-2
Chlorinated Dioxin/Furan Stack Emissions at WTI Facility[a]

Date	Type of Testing	Tests Performed	Chlorine Feed Rate (lb/hr)	Total Emissions (ng/dscm)[b]	TEQ Emissions (ng/dscm)[c]	TEQ Emission Rate (g/sec)
Pre-ECIS[d]						
March 1993	Trial Burn	Condition 1	3090	210	2.45	6.4E-08
		Condition 2	3117	66.4	0.82	2.0E-08
		Condition 3	3102	115	· 1.08	3.0E-08
Post-ECIS[d]						
August 1993	Performance Test	Run 1	2386	6	0.10	1.7E-09
		Run 2	2573	7	0.12	2.1E-09
		Run 3	2351	39	0.27	3.8E-09
		Run 4	2387	6	0.11	2.1E-09
		Run 5	1823	6	0.11	2.2E-09
February 1994	Performance Test	Run 1	2530	8.8	0.045	1.2E-09
		Run 2	2103	3.2	0.019	5.5E-10
		Run 3	1790	4.8	0.028	7.8E-10
		Run 4	1970	5.0	0.029	8.3E-10
		Run 5	1500	4.9	0.035	9.6E-10
February 1994	Trial Burn (Re-run of Condition 2)[e]	Run 1	2958	6.2	0.084	1.2E-09
		Run 2	3304	4.9	0.072	1.0E-09
		Run 3	3231	3.7	0.057	8.3E-10
		Run 4	3109	3.6	0.056	8.5E-10
April 1994	Performance Test	Run 1	2459	4.5	0.037	4.9E-10
		Run 2	2234	4.8	0.036	4.6E-10
		Run 3	2004	3.4	0.035	4.3E-10
		Run 4	2109	2.5	0.032	4.5E-10
		Run 5	1389	3.5	0.033	3.4E-10
August 1994	Performance Test	Run 1	1049	1.7	0.017	2.6E-10
		Run 2	411	0.7	0.010	1.5E-10
		Run 3	414	1.2	0.016	2.3E-10
		Run 4	390	1.0	0.017	2.4E-10
		Run 5	1904	1.4	0.018	2.4E-10
		Run 6	1017	1.5	0.021	2.8E-10
		Run 7	399	1.9	0.021	3.0E-10

Notes:

[a] All emissions testing was performed with a kiln temperature in the range 2,150-2,200°F.

[b] Measurements were taken of all dioxin and furan congeners containing four to eight chlorine s3ubstituents with chlorines in the 2-, 3-, 7-, and 8- positions; the reported value represents the sum of these congeners.

[c] The tetra- through octa- chlorinated dioxin and furan congeners are expressed on the basis of toxicity equivalents (TEQs); the reported value is derived by multiplying the measured emissions of each congener by its toxic equivalency factor (TEF) and then summing the results.

[d] An enhanced carbon injection system (ECIS) was added to the incinerator after the results of the trial burn (Pre-ECIS) demonstrated that dioxin and furan emissions levels were higher than expected. All subsequent operations and emissions testing occurred with the ECIS in place (Post-ECIS).

[e] WTI did not achieve a 99.99% DRE in Condition 2 of the trial burn and therefore repeated this Condition in February 1994.

	TABLE II-3 Key Assumptions for Chapter II		
Assumption	**Basis**	**Magnitude of Effect**	**Direction of Effect**
In applying the waste profile data, individual waste streams that comprise less than 0.5% of the total volume are deleted	The small quantities of these waste streams limit their effect, so this simplifying assumption focuses the assessment on the waste streams that present the most significant health hazard	low	underestimate
In estimating the constituent content in a waste stream, the upper bound of the reported range for each waste stream constituent is used. To prevent the combined percentage from exceeding 100%, the constituent contents of the waste streams are normalized.	Conservative estimate. Professional judgment based on facility design and operation, and predicted waste characterization.	low	overestimate
The waste feed data are based on waste profile sheets for the first year of operation.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics and receiving patterns.	medium	unknown

FIGURE II-1:
Total Chlorinated Dioxin/Furan Emissions vs. Chlorine Feed Rate

FIGURE II-2:
TEQ Emissions vs. Chlorine Feed Rate
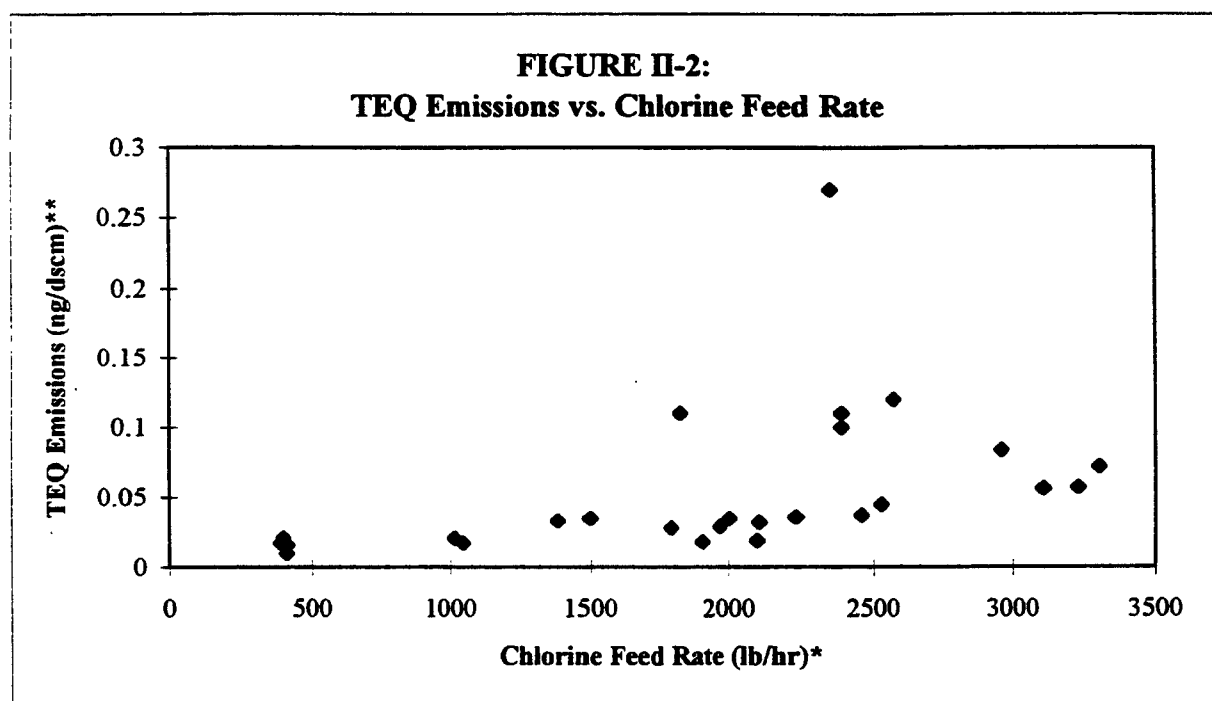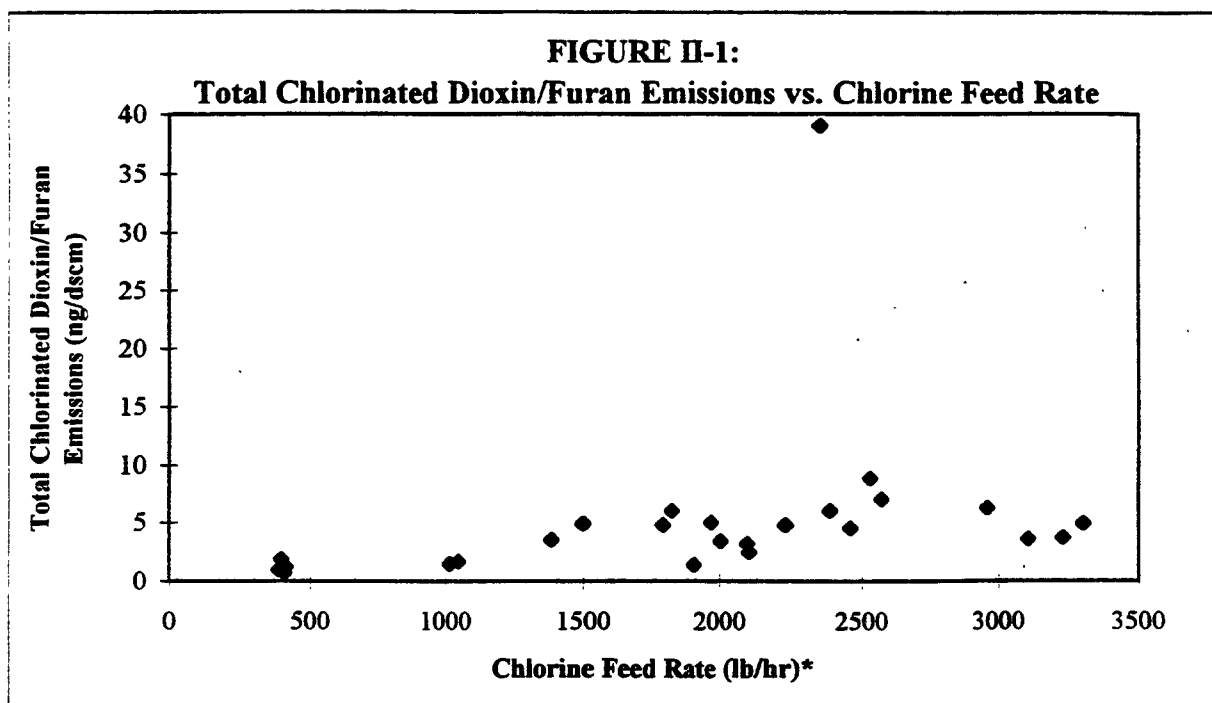
* Feed rate for chlorine in waste feed to incinerator (lb/hr).
** Polychlorinated dioxin/furan emissions expressed as Toxicity Equivalents (TEQs), in nanograms
per dry standard cubic meter (ng/dscm). Results are from the 26 post-ECIS runs.

III. INCINERATOR STACK EMISSIONS

A. Substances of Potential Concern in Stack Emissions

An initial list of substances of potential concern in the stack gases has been developed for the purposes of the risk assessment using the analytical results from the trial burns and performance tests. This list is supplemented by adding substances recommended for inclusion by the peer review committee (U.S. EPA 1993c) and PICs recommended for inclusion by U.S. EPA (1994a) in the *Implementation Guidance for Conducting Indirect Exposure Analysis at RCRA Combustion Facilities*. This listing, which consists of 174 organic residues and PICs, 17 PCDD/PCDF congeners, 15 metals, 3 acid gases, and particles is presented in Table III-1. All of the 17 PCDD/PCDF congeners and 3 acid gases were detected in the WTI stack testing, as were 7 of the 15 metals and 32 of the 174 organic residues and PICs.

B. Development of Chemical-Specific Stack Emission Rates

Due to the different sources of emission information used to characterize stack emissions in this risk assessment, and because of the different mechanisms associated with the generation of different categories of pollutants, different approaches must be utilized in the treatment of source data. Statistical approaches are used where possible, as described below:

- For those chemical constituents where a reasonable number of detailed stack test runs were conducted (e.g., PCDD/PCDF and many "nondioxin PICs"), a statistical approach is used to develop representative "average" and "high end" values.

- For those chemical constituents where representative test data are not available and emissions must be estimated, conservative high-end estimates are consistently used. Since, in these cases, only one value is available (i.e., the highest estimate), a statistical approach can not be used. Thus, certain tables in this document report both the "average" and "high-end" values for certain constituents as being the same (or, more precisely, the "average" value is set equal to the "high-end" value). This approach is deemed to be a conservative way of treating these estimated values.

- Unlike organic PICs, stack emissions of metals are directly related to estimated input feed. Because these emissions vary with the feed material, estimates of the quantities of metals in the feed material are essential to the calculation of emissions. However, since these feed estimates are based on conservative single-value summations of projected quantities over the first year of WTI's operation, a statistical approach can not be used for the metals emissions. The approach used is deemed to be conservative, i.e., it is expected that actual emissions of metals would be less than the values used in the risk assessment.

The specific approaches used to develop stack emission rate estimates for the WTI facility are discussed separately below for PCDDs/PCDFs, other PICs and organic residues, metals, acid gases, and particles.

1. Chlorinated Dioxins and Furans (PCDDs/PCDFs)

The precise mechanism by which PCDDs/PCDFs result in incinerator stack emissions is not completely understood. While it is possible that PCDDs/PCDFs may already be present in trace concentrations in some hazardous waste feed streams, it is generally acknowledged that these compounds are more typically formed in the combustion or post-combustion zone of the incinerator through reactions involving chlorinated organic compounds.

PCDD/PCDF emissions from WTI were first evaluated as part of the March 1993 trial burn, conducted under three different sets of operating conditions. The 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalent (TEQ) emission rates for the three conditions ranged from 20 ng/sec to 64 ng/sec. During a three-day performance test conducted in early August 1993 after installation of the ECIS, PCDD/PCDF measurements were collected under five sets of operating conditions, each at least four hours in duration. Total TEQ emission rates for the five runs ranged from 1.7 ng/sec to 3.8 ng/sec, with an average of 2.4 ng/sec, more than an order of magnitude below the emissions recorded from the March 1993 trial burn. These results indicated that the ECIS had significantly reduced PCDD/PCDF emissions from the facility.

Additional trial burn and performance tests including PCDD/PCDF measurements were conducted in February, April, and August 1994. The results of these tests confirmed the effectiveness of the ECIS in reducing PCDD/PCDF emissions from the facility. The total TEQ emission rates for the performance tests and trial burn (total of nine runs) in February 1994 ranged from 0.55 ng/sec to 1.2 ng/sec, with an average of 0.91 ng/sec. The total TEQ emission rates for the five runs in April 1994 ranged from 0.34 to 0.49 ng/sec, with an average of 0.43 ng/sec, and the total TEQ emission rates

for the seven runs in August 1994 ranged from 0.15 to 0.30 ng/sec, with an average of 0.24 ng/sec. Thus, the dioxin/furan emission rates from the August 1994 performance test are approximately 100-fold lower than the original March 1993 trial burn results. Appendix III-2 presents the dioxin and furan sampling results from the individual trial burns and performance tests.

Since repeated testing at the WTI facility has confirmed the effectiveness of the ECIS, estimates of PCDD/PCDF emission rates in the risk assessment are based on emission data from the post-ECIS installation tests taken through August 1994. These data are summarized in Table III-2. Specifically, average emission rates for the 17 PCDD/PCDF congeners (listed in Table III-2) are calculated as the arithmetic mean of the emission rates measured in the 26 post-ECIS installation test runs taken through August 1994. Individual PCDD/PCDF congeners not detected during a specific run are assumed to be present at one-half of the detection limit for the congener during that run.

The variability of the PCDD/PCDF emission measurements is evaluated by estimating high-end emission rates. High-end emission rates are estimated based on the 95 percent upper confidence limit (UCL)[3] of the arithmetic mean of the 26 post-ECIS installation performance test runs (assuming a normal distribution) or the maximum detected value, whichever is smaller, in accordance with U.S. EPA guidance for calculating the likely upper bound on mean data (U.S. EPA 1992b). In estimating high-end emission rates, PCDD/PCDF congeners that were not detected in a specific run are conservatively assumed to be present at the detection limit for the congener in that run. The estimated average and high-end emission rates for the 17 dioxin and furan congeners are listed in Table III-2.

2. Other PICs and Organic Residues

Sampling of organic residues and PICs emitted from the WTI facility was conducted during the March 1993 and February 1994 trial burns; testing for PICs was also conducted in August and December 1994. As previously indicated, the results of the

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[3] The 95% UCL is defined as:

$$95\% \ UCL = mean + t_{0.05, \, n-1} \left(\frac{s}{\sqrt{n}} \right)$$

where: t   =   Student-t statistic at 0.05 level of significance with n-1 degrees of freedom
          s   =   sample standard deviation
          n   =   number of samples

December 1994 performance tests were not available in time for inclusion in the risk assessment. Appendix III-3 summarizes which of the 174 organic residues and PICs, listed in Section III.A above, were analyzed for during trial burns and performance tests, and which of these compounds were detected. Table III-3 presents estimated emission rates for the PICs and organic residues, and indicates chemicals for which these rates are based on stack measurements from the August 1994 performance test.

As noted previously, DREs for POHCs were also determined during the March 1993 and February 1994 trial burns. The emission rates of the POHCs measured during the trial burns are not expected to be representative of emission rates during normal commercial operations because the trial burns were conducted using an engineered feed, spiked with POHCs at high concentrations. The PIC emission rates and POHC DREs measured during the trial burns, however, are used to estimate residual organic compound and PIC emissions during normal commercial operations.

Given the conditions under which the trial burns were conducted, the primary source of PIC emission rate estimates for the risk assessment is the extensive sampling of organics conducted during the August 1994 performance tests. This program consisted of collecting samples during seven runs conducted during routine operation of the facility. Samples collected during each of the seven runs were analyzed for a total of 93 organic stack gas constituents in addition to individual congeners of PCDD/PCDF.

For the 93 stack constituents analyzed for in the August 1994 tests, average emission rates in the risk assessment are estimated as the arithmetic mean of the seven runs from the August 1994 sampling. Nineteen PICs or organic residues were detected in measurable quantities in at least one of the seven runs during the August 1994 performance test. Seven compounds -- methylene chloride, carbon disulfide, chloroform, carbon tetrachloride, bromodichloromethane, toluene, and bis(2-ethylhexyl)phthalate -- were detected in measurable quantities in all seven runs. Compounds that were analyzed for but not detected are assumed to exist at one-half the detection limit in the stack gas. High-end emission rates of the PICs and organic residues are estimated based on the 95 percent UCL of the arithmetic mean of the measured PIC emission rates, or the maximum detected concentration, whichever is lower. In estimating high-end emission rates, compounds that were not detected are assumed to be present at the detection limit.

A number of the organic compounds listed in Table III-1 were not analyzed for during the August 1994 testing. For these compounds, emissions are estimated based on the following techniques:

(1) <u>Use of measurements from the trial burns</u> - During the March 1993 and February 1994 trial burns, WTI identified and measured emission rates for a number of PICs. Because the trial burns were conducted using spiked, engineered waste feeds, these results are deemed less representative than subsequent performance tests that involved combustion of actual commercial waste streams. Nonetheless, for PICs detected during the trial burns but not analyzed for during the August 1994 PIC sampling, trial burn results are used to estimate emissions. Compounds that were analyzed for but not detected during the trial burn are assumed to be emitted at one-half the detection limit for the compound.

(2) <u>Application of calculated DRE to typical waste profile</u> - An upper bound DRE is estimated based on the DRE values measured during the three runs of Condition 2 of the March 1993 trial burn. (Condition 2 was selected because it resulted in the lowest DREs, corresponding to the highest POHC emissions). The average of nine DRE values (three runs, three POHCs tested in each) is used to develop the upper-bound DRE. An estimate of uncombusted organic emissions is determined from the organic feed rate and the estimated DREs using the following calculation:

$$E = F \times \left[1 - \frac{DRE}{100} \right] \qquad \text{(III-1)}$$

where:

E	=	emission rate, g/s
F	=	chemical feed rate, g/s
DRE	=	destruction and removal efficiency, %

The estimated worst-case DRE is applied to the feed rates of organic compounds identified from chemical characterization data contained in waste profile sheets provided by WTI (described in Chapter II).

Estimated emission rates are developed using the two approaches described above for the organic compounds not analyzed for during the August 1994 PIC testing. For each chemical, the higher of the emission rates estimated using the two approaches listed above is selected. Using this procedure, only a single emission rate is estimated for each

chemical; consequently, these values are used to represent both average and high-end emission rates. The estimated average and high-end emission rates for the PICs and residual organic compounds from the stack are presented in Table III-3.

It should be noted that 31 of the original list of 174 organic compounds of potential concern were not reported in the waste profile sheets or analyzed for in stack emissions at WTI. Thus, emission rates can not be estimated for these 31 compounds using either of the approaches listed above. It is assumed, therefore, that these compounds are not emitted at significant levels. These PICs are listed in Table III-4. Additionally, it should be noted that the August 1994 PIC testing yielded an emission rate for "m/p-xylene", but not for the individual isomers. It is conservatively assumed, therefore, that the emission rates estimated for "m/p-xylene" combined apply to both m-xylene and p-xylene individually.

3. Metals

While the wastes to be treated at the WTI incinerator are predominantly organic in nature, inorganic substances, such as metals, are expected to be present in many waste streams. Metals that are present in the incinerator feed may evaporate at the high temperatures in the rotary kiln and, subsequently, condense to form aerosols of submicron particles in the cooler, later stages of the incineration process. Although most of the metals would be captured in solid form along with slag and ash, a fraction of each metal is expected to escape the emission control systems and be vented to the atmosphere via the stack.

Emission rates are developed for the ten metals regulated at the WTI facility (antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium) and five additional metals (aluminum, copper, nickel, selenium, and zinc). The behavior of each metal within the incinerator is evaluated based on equilibrium modeling performed for the WTI facility (see Chapter III of Appendix III-1). The model indicates that for the specific operating conditions of interest, emission rates can be estimated based on the system removal efficiency (SRE) data compiled from the trial burn and the projected waste feed data for the WTI facility.

The general equation used to calculate metal emission rates for the incinerator stack is the following:

$$E_i = (1 - SRE_i) \times F_i \qquad \text{(III-2)}$$

where:

E_i =   annual average stack emission rate for metal i, lb/yr

F_i =   annual feed rate for metal i, lb/yr

SRE   =   system removal efficiency, %/100

The trial burn conducted at the facility in March 1993 prior to installation of the ECIS provided SREs for seven metals (antimony, arsenic, beryllium, cadmium, chromium, lead, and mercury). Trial burn data are not available, however, to estimate SREs for the remaining eight metals evaluated in this risk assessment (aluminum, barium, copper, nickel, selenium, silver, thallium, and zinc). For metals where direct SRE measurements were made during the trial burns, the average SRE value from the various sampling runs is used. For metals not analyzed in the March 1993 trial burns, SRE values are extrapolated from the trial burn data for the metals that were tested, considering the results of thermodynamic modeling, as described below.

The behavior of metals in the incinerator train is modeled based on mechanistic theories of metal reactions and particle formation (Barton et al. 1990). Figure III-1 illustrates the pathways metals may take through the WTI incinerator. As illustrated in Figure III-1, metals present in the waste feed may first volatilize, become entrained as particles in the combustion gas stream, or enter the slag. Complex oxidation and reduction reactions can then occur between metals and other reactive elements in the combustion gases in the primary and secondary chamber, creating newly formed metal species with different physical/chemical properties than the metals introduced with the waste feed. When metal speciation is expected to occur, the worst case scenario for oxidation state is assumed. For example, all chromium emissions are assumed to be in the Chromium VI oxidation state (the most toxic form of chromium). Chromium speciation is further discussed in Chapter V.

As the combustion gas cools after it exits the secondary combustion chamber, a portion of the metals will condense to form new particles, or condense on the surfaces of the entrained ash particles. The formed particles collide with one another and with the entrained ash. Investigations of combustion systems have found that any particles smaller than about 0.1 μm quickly coagulate, while those larger than 1 μm do not (Linak and Wendt 1993). Thus, two groups of particles typically enter the air cleaning system: one group ranges in size from 0.1 to 1 μm and is formed from the metals that vaporized and subsequently condensed (fine particles); the second group is generally in the range of 1 to 10 μm in diameter and consists of the material entrained in the incinerator (coarse particles).

After exiting the boiler, the cooled combustion gases enter the air pollution control (APC) system. The mechanism of metal removal in the APC system differs from metal to metal, and is largely a function of two characteristics: vapor solubility and particle size. A detailed description of the methods used to model metal behavior in the APC system is contained in Appendix III-1. The primary assumptions and determinations made in conducting the analyses include the following:

- The compounds $PbCl_4$ and CrO_2Cl_2 are commonly predicted to form at low temperatures by the thermodynamic programs, but are not typically found in combustion gases (Linak and Wendt 1993). Thus, these two compounds are excluded from consideration during the thermodynamic modeling.

- MAEROS, a computer model which simulates the behavior of suspended particles (Gelbard 1980), is used to examine the evolution of an aerosol in the WTI incinerator in studying coagulation processes. Based on the modeling results, all metals that vaporize and subsequently condense form particles with diameters of about 0.5 μm.

- All of the ash in the non-pumpable waste is assumed to be incorporated into the slag. Little of the slag is entrained due to its viscous nature. Since the ash for the non-pumpable waste is incorporated into the slag, it is concluded that none of the ash for the non-pumpable waste would be entrained.

- All of the pumpable waste is injected through a sludge lance, a slurry burner, or a liquid burner. These devices cause the wastes to separate into small drops that form solid particles as volatile compounds are released from the drops. Most of these particles are entrained. Thus, it is assumed that all of the ash in the pumpable wastes is entrained.

- Based on classical condensation theory, it has been determined that very little condensation occurs onto the surface of the larger entrained particles (Friedlander 1977; McNallan et al. 1981).

Based on the modeling, metals in the incineration system are classified into one of four categories depending on their expected behavior in the incinerator system: 1) insoluble vapor; 2) soluble vapor; 3) fine particles (<1 μm); and 4) coarse particles (1-10 μm). Soluble and insoluble vapors are created by metals that vaporize in the

incinerator, but do not condense in the quench system. Fine particles vaporize in the incinerator but subsequently condense in the quench system. Coarse particles are largely created by atomization of the waste and do not originate as vapors. The metals evaluated in the risk assessment are categorized as follows:

Form of Metal	SRE Measured in WTI Trial Burn	SRE Not Measured in WTI Trial Burn
Insoluble vapor	Mercury	--
Soluble vapor	--	Selenium
Fine particles	Arsenic, Antimony, Beryllium, Cadmium, Lead	Barium, Copper, Nickel, Silver, Thallium, Zinc
Coarse particles	Chromium	Aluminum

The SREs measured for the seven metals of potential concern tested in the trial burn are shown in Table III-5. Based on the modeling, chromium is used to estimate the SRE for aluminum (coarse particles) and arsenic is used to estimate SREs for barium, copper, nickel, silver, thallium, and zinc. Arsenic is conservatively selected to represent metals on fine particles because it had the lowest measured SRE during the trial burn. No metal analyzed for during the WTI trial burn is classified as a soluble vapor. Thus, another monitored substance that is present in the flue gas as a soluble vapor must be identified to establish the ability of the flue gas cleaning system to remove this class of material. Of the two substances identified, SO_x and HCl, SO_x generally exhibits lower solubilities and lower removal efficiencies than HCl. Thus, the removal efficiency of SO_x is selected as a conservative estimate of the ability of the flue gas cleaning system to capture soluble vapors.

It should be noted that an SRE of zero is assumed for mercury, i.e., there would be no mercury removal in the APC. This is based on the very low SRE (<10%) measured for mercury in the March 1993 trial burn, prior to installation of the ECIS. However, the ECIS may significantly increase the SRE for mercury. For example, a medical waste incinerator in Morristown, NJ, observed a mercury SRE increase from an average of $\approx$ 30% (based on three runs) to an average of $\approx$90% (based on three runs) after installation of an APC (Radian 1992). However, it is conservatively assumed in the risk assessment that the ECIS would not enhance mercury removal in the APC system.

Waste feed data for the 15 metals of potential concern are developed based on waste profile sheets and feed rates provided by WTI for the first year of operation at the facility, as discussed in Chapter II of this volume. Because data from the first year of operation may not represent the maximum operating capacity of the system, the estimated metal feed rates are prorated to account for the maximum heat input of the

incinerator. Therefore, the metal feed rates are multiplied by the ratio of the maximum heat input rate based on the design of the kiln to the heat input rate derived from the waste profile data sheets to develop maximum predicted metals feed rates, which are listed in Table III-5. The maximum permitted heat input is 97.8 million BTU per hour (MMBTU/hr) on a lower heating value basis. This corresponds to a higher heating value of approximately 121 MMBTU/hr. The annualized heat input rate derived for the waste profile is 29.5 MMBTU/hr on a higher heating value basis. Corresponding metal emission rates, calculated using the measured or estimated SRE values along with the maximum predicted metal feed rates, are also listed in Table III-5.

Emission rates of metals are strongly influenced by the metal composition in the feed to the incinerator, and the variability in the SREs for the individual metals in the incineration system. Since the feed composition of metals is highly variable, high-end emission rates are not distinguished from average emission rates (i.e., high-end estimates of metal emission rates are developed and are used to represent average metal emission rates).

4. Acid Gases

A variety of acid gases, including hydrogen chloride (HCl), nitrogen oxides (NO_x), and sulfur oxides (SO_x), may be formed during the incineration of hazardous wastes. The extent to which acid gases are generated and released from an incinerator is primarily related to waste composition, incinerator design and operation, and the effectiveness of pollution control equipment.

WTI measured emissions of HCl during the March 1993 trial burn (nine runs) and the February 1994 trial burn (four runs). The average emission rate of HCl was calculated to be 0.25 lb/hr (0.032 g/sec) using 12 of the 13 trial burn runs (one run in the February 1994 trial burn was prematurely terminated and was not used to estimate the HCl emission rate). This emission rate is considerably below the regulatory limit of 4 lb/hr (40 CFR 264.343b). The HCl control efficiency was not substantially affected by the installation of the ECIS.

During the trial burns, the total chlorine feed rate to the incinerator ranged between 2,960 and 3,300 pounds per hour. According to WTI, typical chlorine feed rates rarely exceed 800 pounds per hour during actual operation (personal communication, G. Victorine 1995). Thus, the HCl emission rates, which are related to the chlorine feed rates, may be significantly overestimated.

WTI continuously monitors stack emissions of NO_x and SO_x and makes the results available on an electronic bulletin board. Average emission rates of NO_x and SO_x are

estimated based on the mean of one randomly selected month of recent continuous monitoring data (February 23, 1995 to March 21, 1995).

Average emission rates of the three acid gases considered in this assessment are presented in Table III-6.

5. Particles

Particle emission rates were measured by WTI during the March 1993 trial burn (nine runs), February 1994 trial burn (four runs), and four performance tests (22 runs combined).[4] The average particle emission rates is estimated as the arithmetic mean of these runs, respectively. The estimated average particle emission rate is 0.07 g/sec. As discussed in Appendix III-1, almost all the particles are less than 10 μm in diameter. The estimated average emission rate of particles is shown in Table III-6.

C. Determination of Emissions Partitioning

Substances in the stack gas will generally be present in either the vapor phase (e.g., volatile organic compounds, acid gases, and mercury) or the particle phase (e.g., metals and condensed organic compounds). As the gases exit the stack, substances in the vapor phase will either remain in the vapor phase or become adsorbed to particles that are present in the stack gases and the atmosphere. This partitioning between phases is based on chemical-specific parameters, and is an important factor in estimating the rate at which compounds deposit out of the atmosphere onto soil, surface water, and plants. Due to their physical/chemical properties, such as vapor pressure, acid gases remain in the vapor phase, metals (with the exception of mercury) remain entirely as particles, while most organics tend to partition between the particle and vapor phases. Some of the polycyclic aromatic hydrocarbons (PAHs) with very low vapor pressures (e.g., dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene) are assumed to be entirely in the particle phase.

1. Partitioning of Emissions Between the Vapor and Particle Phases

The degree to which a vapor-phase chemical will attach to suspended particles is a function of the amount of suspended particles in air and the vapor pressure of the chemical. The fraction of a chemical that is adsorbed to particles is estimated using a theoretical model presented by Junge (1977), whereby:

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[4] Particle sampling was conducted during 23 performance test runs. However, the particle concentration in one performance test was reported as zero, presumably due to either sampling or laboratory error. Thus, only the results from the 22 tests with non-zero particle concentrations are used in the risk assessment.

$$\phi = \frac{c \times S_T}{p^o + (c \times S_T)}$$ (III-3)

where:

ϕ = fraction of organic chemical adsorbed to particles, unitless

S_T = particle surface area per unit volume of air, cm^2/cm^3

p^o = vapor pressure, atm

c = molecular weight and heat of condensation factor, atm-cm

For particles, surface area per unit volume of air (S_T) is assumed to be 3.5 x 10^{-6} cm^2/cm^3, which corresponds to a value for "background plus local sources" (Bidleman 1988). This value is the most appropriate value available for this parameter given the commercial/industrial area around the WTI facility. Other values of particle surface area per unit volume cited by Bidleman (1988) include 4.2 x 10^{-7} cm^2/cm^3 for clean continental background; 1.5 x 10^{-6} cm^2/cm^3 for average background; and 1.1 x 10^{-5} cm^2/cm^3 for urban air. The molecular weight and heat of condensation factor (c) does not vary much between compounds and is estimated to be 1.7 x 10^{-4} atm-cm (Junge 1977; Bidleman 1988).

For compounds with melting points higher than ambient temperature (i.e., compounds that are solid at ambient temperature, such as dioxin- and furan-like compounds and some semi-volatile organic compounds), Bidleman (1988) and U.S. EPA (1994a) recommend that the sub-cooled liquid vapor pressure, P_L, be used as the vapor pressure in the above equation, because it compares more favorably with field data. The value of P_L is estimated using the following equation:

$$\ln\frac{P_L}{P_S} = \frac{\Delta S_f(T_m - T)}{RT}$$ (III-4)

where:

P_L = sub-cooled liquid vapor pressure, atm

P_S = crystalline solid vapor pressure, atm

ΔS_f = entropy of fusion, atm-m^3/mole-K

T_m = melting point, K

T = ambient air temperature, K

R   =   universal gas constant, atm-m³/mole-K

Bidleman (1988) reports that $\Delta S_f/R$ can be satisfactorily estimated as 6.79. Partition factors calculated for substances evaluated in the human health and ecological risk assessments are presented in Volume V.

2. Distribution of Constituents Emitted on Particles

Two separate approaches are used for organics and metals in determining the physical distribution of a chemical on or within a particle in the stack gas. It is assumed that a portion of the organic compounds, which would be in the vapor phase exiting the combustor, adsorb onto the outer surface of airborne particles as condensation occurs in the cooler regions of the post-combustion zone (i.e., surface distribution). Metals are assumed to be homogeneously dispersed throughout the entire particle (i.e., mass distribution) because they may form particles themselves rather than condensing onto existing particles. Therefore, for organics, deposition on particles is a function of the total surface area of particles emitted from the stack; whereas, for metals, deposition is a function of the total mass. The type of distribution (mass versus surface area) that occurs is accounted for in the air dispersion modeling, as described in Volume IV.

D. Key Assumptions for Incinerator Stack Emissions

The key assumptions used in predicting and analyzing incinerator stack emissions for the WTI facility are summarized in Table III-7. This table indicates the basis for the assumptions listed, the estimated relative magnitude of these assumptions' effect on the overall risk assessment, and the direction of the effect, if known. These assumptions are further discussed in Chapter V of this report.

PICs and Residual Organic Compounds

Acenaphthene	Chlorophenol, 2-	Ethyl methacrylate
Acenaphthylene	Chlorodiphenylether, 4-	Ethylbenzene
Acetaldehyde	Chloropropane, 2-	Ethylene dibromide
Acetone	Chrysene	Ethylene oxide
Acetophenone	Cresol, m-	Ethylene thiourea
Acrolein	Cresol, o-	Fluoranthene
Acrylonitrile	Cresol, p-	Fluorene
Anthracene	Crotonaldehyde	Formaldehyde
Benzaldehyde	Cumene	Furfural
Benzene	2,4-D	Heptachlor
Benzoic acid	4,4'-DDE	Heptachlorobiphenyl
Benzotrichloride	Dibenz(a,h)anthracene	Hexachlorobenzene
Benzo(a)anthracene	Dibenz(a,h)fluoranthene	Hexachlorobiphenyl
Benzo(a)pyrene	Dibromo-3-chloropropane, 1,2-	Hexachlorobutadiene
Benzo(b)fluoranthene	Dibromochloromethane	Hexachlorocyclohexane, alpha-
Benzo(e)pyrene	Dichloro-2-butene, cis-1,4-	Hexachlorocyclohexane, beta-
Benzo(g,h,i)perylene	Dichloro-2-butene, trans-1,4-	Hexachlorocyclohexane, gamma-
Benzo(j)fluoranthene	Dichlorobenzene, 1,2-	(a.k.a. Lindane)
Benzo(k)fluoranthene	Dichlorobenzene, 1,3-	Hexachlorocyclopentadiene
Benzyl chloride	Dichlorobenzene, 1,4-	Hexachloroethane
Biphenyl	Dichlorobenzidine, 3,3'-	Hexachlorophene
Bis(2-chloroethoxy) methane	Dichlorobiphenyl	Hexane, n-
Bis(2-chloroethyl)ether	Dichlorodifluoromethane	Hexanone, 2-
Bis(2-chloroisopropyl)ether	Dichloroethane, 1,1-	Hexanone, 3-
Bis(2-ethylhexyl)phthalate	Dichloroethane, 1,2-	Indeno(1,2,3-cd)pyrene
Bromochloromethane	Dichloroethene, 1,1-	Isophorone
Bromodichloromethane	Dichloroethylene, trans-1,2-	Maleic hydrazide
Bromoethene	Dichlorofluoromethane	Methoxychlor
Bromoform	Dichlorophenol, 2,4-	Methylene bromide
Bromomethane	Dichloropropane, 1,2-	Methylene chloride
Bromodiphenylether, p-	Dichloropropene, cis-1,3-	Methylnaphthalene, 2-
Butadiene, 1,3-	Dichloropropene, trans-1,3-	Methyl-tert-butyl ether
Butanone, 2- (MEK)	Diethylphthalate	Methyl-2-Pentanone, 4-
Butylbenzylphthalate	Dimethoxybenzidine, 3,3'-	Monochlorobiphenyl
Carbon disulfide	Dimethylphenol, 2,4-	Naphthalene
Carbon tetrachloride	Dimethylphthalate	Nitroaniline, 2-
Chlordane	Di-n-butylphthalate	Nitroaniline, 3-
Chloro-3-methylphenol, 4-	Di-n-octyl phthalate	Nitroaniline, 4-
Chloroacetophenone, 2-	Dinitritoluene, 2,6-	Nitrobenzene
Chloroaniline, p-	Dinitro-2-methylphenol, 4,6-	Nitrophenol, 2-
Chlorobenzene	Dinitrobenzene, 1,2-	Nitrophenol, 4-
Chlorobenzilate	Dinitrobenzene, 1,3-	N-Nitroso-di-n-butylamine
Chloroethane	Dinitrobenzene, 1,4-	N-Nitroso-di-n-propylamine
Chloroform	Dinitrophenol, 2,4-	N-Nitrosodiphenylamine
Chloromethane	Dinitrotoluene, 2,4-	Nonachlorobiphenyl
Chloronaphthalene, beta	Dioxane, 1,4-	Octachlorobiphenyl

TABLE III-1 (continued)		
Substances of Potential Concern in Stack Emissions		
Pentachlorobenzene	Styrene	Trichlorobiphenyl
Pentachlorobiphenyl	Tetrachlorobenzene, 1,2,4,5-	Trichloroethane, 1,1,1-
Pentachloronitrobenzene	Tetrachlorobiphenyl	Trichloroethane, 1,1,2-
Pentachlorophenol	Tetrachloroethane, 1,1,1,2-	Trichloroethene
Phenanthrene	Tetrachloroethane, 1,1,2,2-	Trichlorofluoromethane
Phenol	Tetrachloroethene	Trichlorophenol, 2,4,5-
Phosgene	Tetrachlorophenol, 2,3,4,6-	Trichlorophenol, 2,4,6-
Propionaldehyde	Toluene	Trichloropropane; 1,2,3-
Pyrene	Toluidine, o-	Vinyl acetate
Quinoline	Toluidine, p-	Vinyl chloride
Quinone	Trichloro-1,2,2-TFE, 1,1,2-	Xylene, m-
Safrole	Trichlorobenzene, 1,2,4-	Xylene, o-
		Xylene, p-

Dioxin Congeners	Furan Congeners	
2,3,7,8-TetraCDD		
1,2,3,7,8-PentaCDD	2,3,7,8-TetraCDF	1,2,3,7,8,9-HexaCDF
1,2,3,4,7,8-HexaCDD	1,2,3,7,8-PentaCDF	2,3,4,6,7,8-HexaCDF
1,2,3,6,7,8-HexaCDD	2,3,4,7,8-PentaCDF	1,2,3,4,6,7,8-HeptaCDF
1,2,3,7,8,9-HexaCDD	1,2,3,4,7,8-HexaCDF	1,2,3,4,7,8,9-HeptaCDF .
1,2,3,4,6,7,8-HeptaCDD	1,2,3,6,7,8-HexaCDF	OctaCDF
OctaCDD		

Metals		
Aluminum	Cadmium	Mercury (inorganic and organic)
Antimony	Chromium (hexavalent and	Nickel
Arsenic	trivalent)	Selenium
Barium	Copper	Silver
Beryllium	Lead	Thallium
		Zinc

Acid Gases
Hydrogen chloride
Total nitrogen oxides (NO_x)
Total sulfur oxides (SO_x)

Particulate Matter
Respirable (PM_{10})
Total

Notes:

TFE	-	trifluoroethane	MEK	-	methyl ethyl ketone
CDD	-	chlorodibenzo-p-dioxin	PM_{10}	-	particulate matter <10 microns
CDF	-	chlorodibenzofuran			

TABLE III-2 Estimated Average and High-end Stack Emission Rates for Dioxin and Furan Congeners		
Congener	**Emission Rate (g/sec)**	
	Average	**High-end**
Dioxin Congeners		
2,3,7,8-TetraCDD	1.08×10^{-11}	2.16×10^{-11}
1,2,3,7,8-PentaCDD	6.78×10^{-11}	9.46×10^{-11}
1,2,3,4,7,8-HexaCDD	8.95×10^{-11}	1.25×10^{-10}
1,2,3,6,7,8-HexaCDD	1.66×10^{-10}	2.18×10^{-10}
1,2,3,7,8,9-HexaCDD	1.09×10^{-10}	1.55×10^{-10}
1,2,3,4,6,7,8-HeptaCDD	1.24×10^{-9}	1.69×10^{-9}
OctaCDD	6.15×10^{-9}	9.80×10^{-9}
Furan Congeners		
2,3,7,8-TetraCDF	8.77×10^{-11}	1.15×10^{-10}
1,2,3,7,8-PentaCDF	3.45×10^{-10}	4.35×10^{-10}
2,3,4,7,8-PentaCDF	4.67×10^{-10}	6.04×10^{-10}
1,2,3,4,7,8-HexaCDF	1.43×10^{-9}	1.85×10^{-9}
1,2,3,6,7,8-HexaCDF	1.33×10^{-9}	1.71×10^{-9}
2,3,4,6,7,8-HexaCDF	1.50×10^{-9}	1.96×10^{-9}
1,2,3,7,8,9-HexaCDF	2.93×10^{-10}	3.85×10^{-10}
1,2,3,4,6,7,8-HeptaCDF	9.30×10^{-9}	1.30×10^{-8}
1,2,3,4,7,8,9-HeptaCDF	1.22×10^{-9}	1.80×10^{-9}
OctaCDF	1.89×10^{-8}	3.62×10^{-8}

Notes:

CDD - chlorodibenzo-p-dioxin
CDF - chlorodibenzo-p-furan

TABLE III-3 Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds			
Substance	Emission Rate (g/sec)		Source
	Average	High-end	
Acenaphthene	6.69×10^{-6}	6.69×10^{-6}	a
Acenaphthylene	6.69×10^{-6}	6.69×10^{-6}	a
Acetaldehyde	3.01×10^{-4}	3.01×10^{-4}	a
Acetone	2.90×10^{-3}	2.90×10^{-3}	a
Acetophenone	2.93×10^{-4}	2.93×10^{-4}	a
Acrylonitrile	2.02×10^{-4}	2.02×10^{-4}	a
Anthracene	5.50×10^{-6}	1.10×10^{-5}	b
Benzene	1.47×10^{-5}	2.63×10^{-5}	b
Benzoic acid	1.13×10^{-5}	1.13×10^{-5}	a
Benzotrichloride	3.20×10^{-5}	3.20×10^{-5}	a
Benzo(a)anthracene	5.50×10^{-6}	1.10×10^{-5}	b
Benzo(a)pyrene	5.50×10^{-6}	1.10×10^{-5}	b
Benzo(b)fluoranthene	5.50×10^{-6}	1.10×10^{-5}	b
Benzo(g,h,i)perylene	5.50×10^{-6}	1.10×10^{-5}	b
Benzo(k)fluoranthene	5.50×10^{-6}	1.10×10^{-5}	b
Bis(2-chloroethoxy)methane	6.69×10^{-6}	6.69×10^{-6}	a
Bis(2-chloroethyl)ether	1.33×10^{-5}	1.33×10^{-5}	a
Bis(2-chloroisopropyl)ether	6.69×10^{-6}	6.69×10^{-6}	a
Bis(2-ethylhexyl)phthalate	3.72×10^{-5}	5.23×10^{-5}	b
Bromodichloromethane	1.03×10^{-4}	1.53×10^{-4}	b
Bromoform	5.50×10^{-6}	1.10×10^{-5}	b
Bromomethane	4.90×10^{-4}	9.80×10^{-4}	b
Bromodiphenylether, p-	6.69×10^{-6}	6.69×10^{-6}	a

TABLE III-3 (continued) Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds			
Substance	Emission Rate (g/sec)		Source
	Average	High-end	
Butanone, 2-	5.14×10^{-5}	7.40×10^{-5}	b
Butylbenzylphthalate	5.50×10^{-6}	1.10×10^{-5}	b
Carbon disulfide	8.91×10^{-5}	9.46×10^{-5}	b
Carbon tetrachloride	1.58×10^{-4}	2.75×10^{-4}	b
Chlordane	5.50×10^{-7}	1.10×10^{-6}	b
Chloro-3-methylphenol, 4-	6.69×10^{-6}	6.69×10^{-6}	a
Chloroaniline, p-	6.69×10^{-6}	6.69×10^{-6}	a
Chlorobenzene	5.50×10^{-6}	1.10×10^{-5}	b
Chlorobenzilate	3.68×10^{-5}	3.68×10^{-5}	a
Chloroethane	4.90×10^{-4}	9.80×10^{-4}	b
Chloroform	2.66×10^{-4}	4.07×10^{-4}	b
Chloromethane	2.45×10^{-4}	4.90×10^{-4}	b
Chloronaphthalene, beta-	6.69×10^{-6}	6.69×10^{-6}	a
Chlorophenol, 2-	5.50×10^{-6}	1.10×10^{-5}	b
Chlorodiphenyl ether, 4-	6.69×10^{-6}	6.69×10^{-6}	a
Chrysene	5.50×10^{-6}	1.10×10^{-5}	b
Cresol, m-	5.50×10^{-6}	1.10×10^{-5}	b
Cresol, o-	5.50×10^{-6}	1.10×10^{-5}	b
Cresol, p-	5.50×10^{-6}	1.10×10^{-5}	b
Crotonaldehyde	1.39×10^{-4}	1.39×10^{-4}	a
Cumene	5.50×10^{-6}	1.10×10^{-5}	b
2,4-D	3.88×10^{-5}	3.88×10^{-5}	a
4,4'-DDE	5.50×10^{-7}	1.10×10^{-6}	b

TABLE III-3 (continued) Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds			
Substance	Emission Rate (g/sec)		Source
	Average	High-end	
Dibenz(a,h)anthracene	5.50×10^{-6}	1.10×10^{-5}	b
Dibenzo(a,h)fluoranthene	5.50×10^{-6}	1.10×10^{-5}	b
Dibromochloromethane	2.63×10^{-5}	2.63×10^{-5}	a
Dichlorobenzene, 1,2-	5.50×10^{-6}	1.10×10^{-5}	b
Dichlorobenzene, 1,3-	5.50×10^{-6}	1.10×10^{-5}	b
Dichlorobenzene, 1,4-	5.50×10^{-6}	1.10×10^{-5}	b
Dichlorobenzidine, 3,3'-	3.33×10^{-5}	3.33×10^{-5}	a
Dichlorobiphenyl	4.68×10^{-8}	8.22×10^{-8}	b
Dichlorodifluoromethane	2.45×10^{-4}	4.90×10^{-4}	b
Dichloroethane, 1,1-	1.25×10^{-5}	2.50×10^{-5}	b
Dichloroethane, 1,2-	1.25×10^{-5}	2.50×10^{-5}	b
Dichloroethene, 1,1-	1.25×10^{-5}	2.50×10^{-5}	b
Dichloroethene, trans-1,2-	1.25×10^{-5}	2.50×10^{-5}	b
Dichlorophenol, 2,4-	5.50×10^{-6}	1.10×10^{-5}	b
Dichloropropane, 1,2-	1.25×10^{-5}	2.50×10^{-5}	b
Dichloropropene, cis-1,3-	1.25×10^{-5}	2.50×10^{-5}	b
Dichloropropene, trans-1,3-	1.25×10^{-5}	2.50×10^{-5}	b
Diethylphthalate	1.69×10^{-5}	3.60×10^{-5}	b
Dimethoxybenzidine, 3,3'-	1.15×10^{-4}	1.15×10^{-4}	a
Dimethylphenol, 2,4-	5.50×10^{-6}	1.10×10^{-5}	b
Dimethylphthalate	5.50×10^{-6}	1.10×10^{-5}	b
Di-n-butylphthalate	1.57×10^{-5}	2.04×10^{-5}	b
Di-n-octyl phthalate	5.50×10^{-6}	1.10×10^{-5}	b

	Emission Rate (g/sec)		
Substance	**Average**	**High-end**	**Source**

TABLE III-3 (continued)
Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds

Substance	Average	High-end	Source
Dinitrotoluene, 2,6-	5.50×10^{-6}	1.10×10^{-5}	b
Dinitro-2-methylphenol, 4,6-	5.50×10^{-6}	1.10×10^{-5}	b
Dinitrophenol, 2,4-	5.50×10^{-6}	1.10×10^{-5}	b
Dinitrotoluene, 2,4-	5.50×10^{-6}	1.10×10^{-5}	b
Dioxane, 1,4-	4.94×10^{-4}	4.94×10^{-4}	a
Ethyl methacrylate	2.45×10^{-4}	4.90×10^{-4}	b
Ethylbenzene	4.98×10^{-4}	7.53×10^{-4}	b
Ethylene dibromide	1.15×10^{-4}	1.15×10^{-4}	a
Ethylene oxide	3.05×10^{-5}	3.05×10^{-5}	a
Ethylene thiourea	1.46×10^{-10}	1.46×10^{-10}	a
Fluoranthene	5.50×10^{-6}	1.10×10^{-5}	b
Fluorene	6.69×10^{-6}	6.69×10^{-6}	a
Formaldehyde	6.07×10^{-4}	6.07×10^{-4}	a
Furfural	5.50×10^{-6}	1.10×10^{-5}	b
Heptachlor	5.50×10^{-7}	1.10×10^{-6}	b
Heptachlorobiphenyl	1.40×10^{-8}	2.80×10^{-8}	b
Hexachlorobenzene	5.50×10^{-6}	1.10×10^{-5}	b
Hexachlorobiphenyl	1.40×10^{-8}	2.80×10^{-8}	b
Hexachlorobutadiene	1.01×10^{-4}	1.01×10^{-4}	a
Hexachlorocyclohexane, gamma- (Lindane)	5.48×10^{-5}	5.48×10^{-5}	a
Hexachlorocyclopentadiene	5.50×10^{-6}	1.10×10^{-5}	b
Hexachloroethane	5.50×10^{-6}	1.10×10^{-5}	b

TABLE III-3 (continued)				
Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds				
Substance	Emission Rate (g/sec)		Source
	Average	High-end	
Hexachlorophene	3.20×10^{-5}	3.20×10^{-5}	a
Hexanone, 2-	6.43×10^{-5}	6.43×10^{-5}	a
Indeno(1,2,3-cd)pyrene	5.50×10^{-6}	1.10×10^{-5}	b
Isophorone	6.69×10^{-6}	6.69×10^{-6}	a
Maleic hydrazide	1.15×10^{-4}	1.15×10^{-4}	a
Methoxychlor	5.50×10^{-7}	1.10×10^{-6}	b
Methylene chloride	3.96×10^{-4}	6.19×10^{-4}	b
Methylnaphthalene, 2-	4.18×10^{-5}	4.18×10^{-5}	a
Methyl-tert-butyl ether	1.25×10^{-5}	2.50×10^{-5}	b
Methyl-2-Pentanone, 4-	1.25×10^{-5}	2.50×10^{-5}	b
Monochlorobiphenyl	1.67×10^{-8}	2.99×10^{-8}	b
Naphthalene	5.50×10^{-6}	1.10×10^{-5}	b
Nitroaniline, 2-	6.69×10^{-6}	6.69×10^{-6}	a
Nitroaniline, 3-	6.69×10^{-6}	6.69×10^{-6}	a
Nitroaniline, 4-	6.69×10^{-6}	6.69×10^{-6}	a
Nitrobenzene	5.50×10^{-6}	1.10×10^{-5}	b
Nitrophenol, 2-	6.69×10^{-6}	6.69×10^{-6}	a
Nitrophenol, 4-	5.50×10^{-6}	1.10×10^{-5}	b
N-Nitroso-di-n-butylamine	1.21×10^{-4}	1.21×10^{-4}	a
N-Nitroso-di-n-propylamine	6.69×10^{-6}	6.69×10^{-6}	a
N-Nitrosodiphenylamine	6.69×10^{-6}	6.69×10^{-6}	a
Nonachlorobiphenyl	1.40×10^{-8}	2.80×10^{-8}	b
Octachlorobiphenyl	1.40×10^{-8}	2.80×10^{-8}	b

| Substance | Emission Rate (g/sec) | | Source |
	Average	High-end	
Pentachlorobenzene	4.76 x 10^{-5}	4.76 x 10^{-5}	a
Pentachlorobiphenyl	1.40 x 10^{-8}	2.80 x 10^{-8}	b
Pentachloronitrobenzene	3.37 x 10^{-5}	3.37 x 10^{-5}	a
Pentachlorophenol	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Phenanthrene	6.69 x 10^{-6}	6.69 x 10^{-6}	a
Phenol	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Pyrene	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Safrole	1.15 x 10^{-4}	1.15 x 10^{-4}	a
Styrene	2.25 x 10^{-5}	4.04 x 10^{-5}	b
Tetrachlorobiphenyl	1.40 x 10^{-8}	2.80 x 10^{-8}	b
Tetrachloroethane, 1,1,1,2-	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Tetrachloroethane, 1,1,2,2-	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Tetrachloroethene	5.13 x 10^{-5}	8.02 x 10^{-5}	b
Tetrachlorophenol, 2,3,4,6-	6.80 x 10^{-6}	6.80 x 10^{-6}	a
Toluene	6.13 x 10^{-4}	1.03 x 10^{-3}	b
Trichloro-1,2,2-trifluoroethane, 1,1,2-	3.30 x 10^{-4}	3.30 x 10^{-4}	a
Trichlorobenzene, 1,2,4-	5.50 x 10^{-6}	1.10 x 10^{-5}	b
Trichlorobiphenyl	3.02 x 10^{-8}	5.80 x 10^{-8}	b
Trichloroethane, 1,1,1-	1.25 x 10^{-5}	2.50 x 10^{-5}	b
Trichloroethane, 1,1,2-	1.25 x 10^{-5}	2.50 x 10^{-5}	b
Trichloroethene	1.86 x 10^{-5}	3.09 x 10^{-5}	b
Trichlorofluoromethane	2.45 x 10^{-4}	4.90 x 10^{-4}	b
Trichlorophenol, 2,4,5-	5.50 x 10^{-6}	1.10 x 10^{-5}	b

TABLE III-3 (continued)
Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds

TABLE III-3 (continued)
Estimated Average and High-end Emission Rates for Products of Incomplete Combustion (PICs) and Residues of Organic Compounds

| Substance | Emission Rate (g/sec) | | Source |
	Average	High-end	
Trichlorophenol, 2,4,6-	5.50×10^{-6}	1.10×10^{-5}	b
Vinyl acetate	6.43×10^{-5}	6.43×10^{-5}	a
Vinyl chloride	2.45×10^{-4}	4.90×10^{-4}	b
Xylene, m-[c]	3.80×10^{-4}	5.64×10^{-4}	b
Xylene, o-	5.50×10^{-6}	1.10×10^{-5}	b
Xylene, p-[c]	3.80×10^{-4}	5.64×10^{-4}	b

Notes:

[a] Emission rate based on March 1993 and February 1994 trial burn results and waste profile information. In these cases, the average and high-end estimates are the same because the estimation method used in this process results in a high-end estimate, which is conservatively assumed to apply to the average case as well.

[b] Emission rate based on August 1994 PIC testing results.

[c] The emission rate for the mixed isomer "m/p-xylene" estimated from the August 1994 PIC testing is conservatively assumed to apply to both m-xylene and p-xylene.

TABLE III-4
Compounds Anticipated to be Emitted in Very Low Quantities for which Emission Rates Are Not Developed

Acrolein	Dinitrobenzene, 1,3-
Benzaldehyde	Dinitrobenzene, 1,4-
Benzo(e)pyrene	Hexachlorocyclohexane, alpha-
Benzo(j)fluoranthene	Hexachlorocyclohexane, beta-
Benzyl chloride	Hexane, n-
Biphenyl	Hexanone, 3-
Bromochloromethane	Methylene bromide
Bromoethene	Phosgene
Butadiene, 1,3-	Propionaldehyde
Chloroacetophenone, 2-	Quinoline
Chloropropane, 2-	Quinone
Dibromo-3-chloropropane, 1,2-	Tetrachlorobenzene, 1,2,4,5-
Dichloro-2-butene, cis-1,4-	Toluidine, o-
Dichloro-2-butene, trans-1,4-	Toluidine, p-
Dichlorofluoromethane	Trichloropropane, 1,2,3-
Dinitrobenzene, 1,2-	

Note:

These compounds were on original list of possible organic constituents of concern, but not reported in Waste Profiles or analyzed for in WTI stack emissions.

TABLE III-5 Estimated Average Metal Emission Rates				
Metal	Measured SRE (percent)	Feed Rate (lb/hr)	Feed Rate (g/sec)	Emission Rate (g/sec)
Aluminum	NA (99.99932[a])	140	18	2.4×10^{-4}
Antimony	99.986	0.24	0.030	4.2×10^{-6}
Arsenic	99.977	1.3	0.16	3.7×10^{-5}
Barium	NA (99.977[b])	5.3	0.67	1.5×10^{-4}
Beryllium	99.9907	0.0028	0.00035	3.3×10^{-8}
Cadmium	99.987	0.96	0.12	1.6×10^{-5}
Chromium	99.99932	0.83	0.10	7.1×10^{-7}
Copper	NA (99.977[b])	3.2	0.41	9.4×10^{-5}
Lead	99.99	3.4	0.44	4.3×10^{-5}
Mercury	0[c]	0.011	0.0014	1.4×10^{-3}
Nickel	NA (99.977[b])	0.17	0.022	5.0×10^{-6}
Selenium	99.68	1.2	0.15	4.7×10^{-4}
Silver	NA (99.977[b])	0.52	0.065	1.5×10^{-5}
Thallium	NA (99.977[b])	1.7	0.15	3.4×10^{-5}
Zinc	NA (99.977[b])	4.2	0.54	1.2×10^{-4}

Notes:

System removal efficiency (SRE) determined from March 1993 trial burn (ENSR 1993)

NA: Not applicable; SRE not determined in March 1993 trial burn (ENSR 1993).

[a]   Estimated based on chromium SRE.

[b]   Estimated based on arsenic SRE.

[c]   Assumed to be zero although very low, non-zero efficiency was measured.

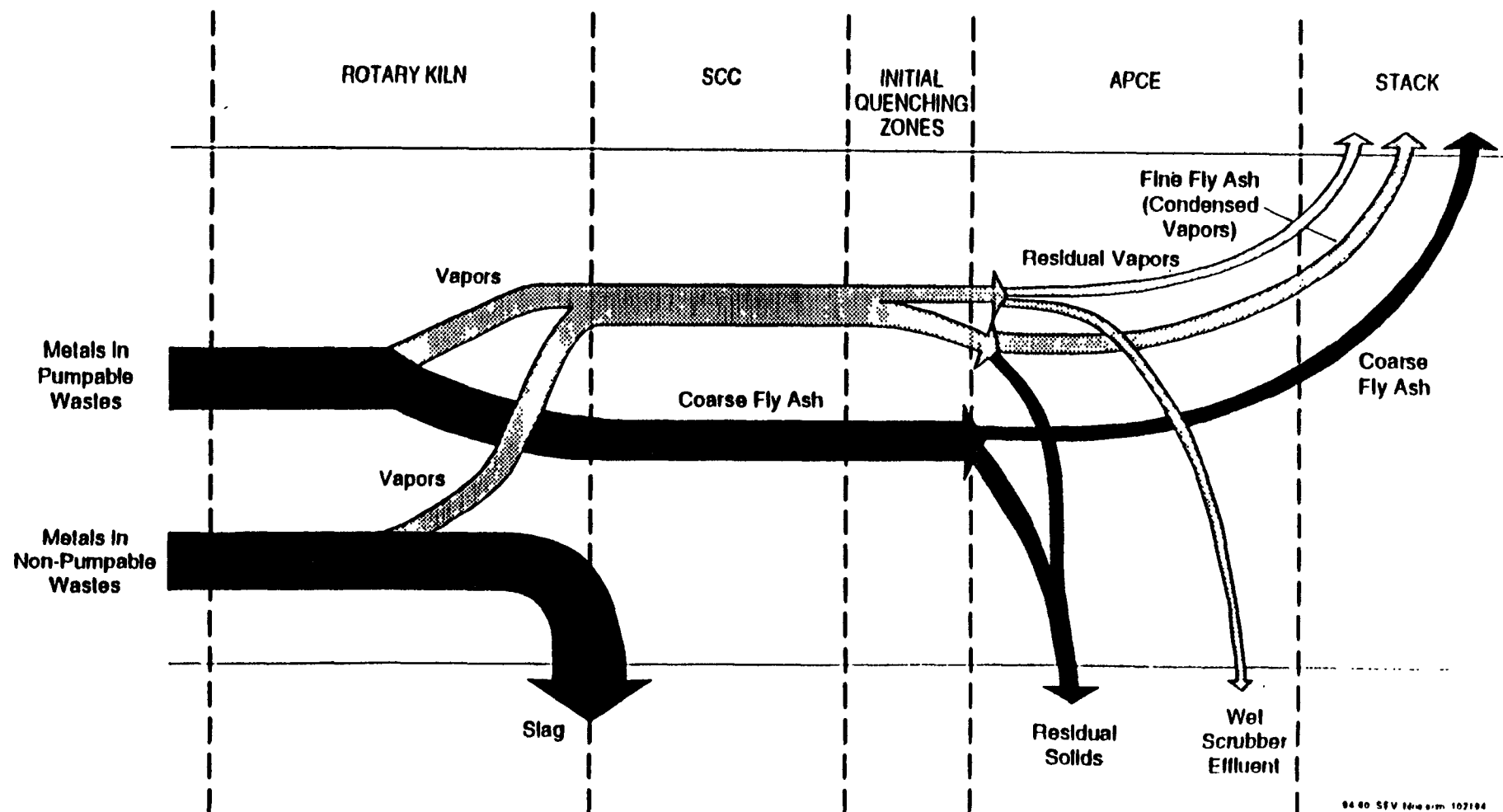| TABLE III-6	
Estimated Average Acid Gas and Particulate Matter Emission Rates	
Substance	**Average Emission Rate (g/sec)**
Hydrogen Chloride	0.032
Nitrogen Oxides	2.4
Sulfur Dioxides	0.091
Particles	0.07
Source: WTI monitoring data; February 23, 1995 to March 21, 1995.	

TABLE III-7			
Key Assumptions for Chapter III			
Assumption	Basis	Magnitude of Effect	Direction of Effect
All stack chemicals of potential concern have been identified and included	The list of COCs have been developed from U.S. EPA guidance documents and stack testing during trial burns and performance tests. Additional substances have been added based on peer review committee recommendations.	low	underestimate
Emission rates are estimated based on performance tests and trial burns and not on long-term emissions data	Long-term data are not available because the facility has only had limited operation. The trial burn data are derived from subjecting the incinerator to extreme conditions not encountered on a regular basis. The results from the trial burn and performance test indicate a decrease in emissions of dioxins/furans over the 1-2 year operating period.	medium	unknown
Average emission rates for the 95th UCL of the individual dioxin and furan congeners are based on the arithmetic mean of 26 post-ECIS runs	The use of average data when a declining trend is apparent overstates long-term emissions.	low	overestimate
Non-detected chemicals equal one-half the detection limit when estimating average emission rates and equal the detection limit when estimating high-end emission rates	U.S. EPA (1989 a,b) guidance was relied upon for the average case and a conservative assumption based on professional judgment was used for the high-end case	low	overestimate
Long-term PIC emission rates are based on the arithmetic mean of seven runs from the August 1994 sampling	The uncertainty of emission estimates decreases as the number of data points increases. The assessment uses all of the data that are available.	medium	unknown

		TABLE III-7 (continued)	
Key Assumptions for Chapter III			

Assumption	Basis	Magnitude of Effect	Direction of Effect
For PICs not analyzed for during the August 1994 testing, emission rates are estimated based on: - Earlier trial burns. These burns are less representative than performance tests of actual operating conditions - The feed rate and a worst-case DRE. The feed rate is developed from waste profile sheets for the first year of operation and the DRE is calculated for three POHCs - The maximum of the estimated emission rates is used. This estimated emission rate is used as both the high-end and average emission rate	The estimation method includes conservative assumptions so emission rates are not likely to be underestimated.	low	overestimate
If no emission rate can be estimated for a chemical, the chemical is dropped from consideration assuming it is not emitted at significant levels	The chemicals that have been dropped are not likely to be emitted in significant quantities, if at all, and are considered in evaluating the uncharacterized fraction.	low	underestimate
Metals emissions are estimated from trial burns, one year of waste feed data, and thermodynamic modeling	Best available data. Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	medium	unknown
The trial burn during which metal SREs were calculated was conducted prior to installation of the ECIS. These SREs are used to estimate metal emission rates.	The ECIS is not designed to appreciably reduce metal emissions, so SREs measured pre-ECIS should be similar to post-ECIS. An exception may be mercury, for which removal may be enhanced by the ECIS.	low	overestimate

TABLE III-7 (continued)			
Key Assumptions for Chapter III			
Assumption	Basis	Magnitude of Effect	Direction of Effect
The thermodynamic modeling to describe metal behavior contains several assumptions including: - PbCl4 and CrO2Cl2 are excluded - All metals that vaporize subsequently condense to form particles with diameters that are 0.5μm - All pumpable waste is entrained and no ash from non-pumpable waste is entrained - Little condensation occurs onto the surface of larger entrained particles	Professional judgment was relied upon based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
As part of the modeling, the following assumptions are applied: - Cr is an appropriate surrogate for Al - As is an appropriate surrogate for Ba, Cu, Ni, Ag, Tl, Zn - SO_2 is an appropriate surrogate for Se - Hg has a zero SRE	The surrogates were selected based on the expected behavior of the metals, which are a function of their physical/chemical characteristics. The trial burn results indicate SREs in a relatively narrow range for most metals, so these assumptions are not expected to have a significant effect.	low	unknown
The metals feed rates are prorated to account for the maximum heat input of the incinerator.	Conservative assumption. Professional judgment was relied upon based on a review of information on facility design and operation, and predicted waste characteristics.	low	overestimate
HCl emission rates are based on the average of 12 trial burn runs	Trial burns were conducted at elevated total chlorine feed rates producing conservative estimates of HCl emission rates.	low	overestimate
Metals (other than Hg) are emitted from the stack in particle form	Metals are generally non-volatile and those that volatilize in the high temperature of the rotary kiln will condense to form aerosols in the cooler, later stages of the incineration process.	low	variable

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<tr>
<th colspan="2" style="text-align:center">TABLE III-7 (continued)
Key Assumptions for Chapter III</th>
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<th style="text-align:center">Basis</th>
<th style="text-align:center">Magnitude of Effect</th>
<th style="text-align:center">Direction of Effect</th>
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<tr>
<td>The vapor/particle partitioning equation (Equation III-3) and associated constants (S_T, c, and $\Delta S_f/R$) are used to describe the partitioning phenomena, with the exception of chemicals with low volatility such as metals and some PAHs.</td>
<td>U.S. EPA guidance indicates that the model is a reasonable estimation of partitioning of organics in air. However, field data show that the model may under-or overpredict vapor/particle partitioning for PAHs and organochlorines.</td>
<td style="text-align:center">high</td>
<td style="text-align:center">variable</td>
</tr>
<tr>
<td>Compounds partition either via surface area distribution or mass distribution, but not in combination.</td>
<td>Simplifying assumption based on theoretical considerations.</td>
<td style="text-align:center">low</td>
<td style="text-align:center">variable</td>
</tr>
<tr>
<td>Assumptions regarding metal modeling:

- Thermodynamic equilibrium is maintained throughout the incineration and flue gas cleaning system
- All important compounds are present in the thermodynamic data base
- The reactor outlet temperature is the temperature to which the metals are exposed</td>
<td>Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.</td>
<td style="text-align:center">medium</td>
<td style="text-align:center">unknown</td>
</tr>
<tr>
<td>Chromium is assumed to exist completely in the hexavalent state</td>
<td>Conservative assumption because hexavalent Cr is more toxic than trivalent.</td>
<td style="text-align:center">low</td>
<td style="text-align:center">overestimate</td>
</tr>
<tr>
<td>Products with low vapor pressures are not likely to exist in the vapor phase</td>
<td>Professional judgement based on a review of information on facility design and operation, and predicted waste characteristics.</td>
<td style="text-align:center">high</td>
<td style="text-align:center">unknown</td>
</tr>
</tbody>
</table>

ROTARY KILN   SCC   INITIAL QUENCHING ZONES   APCE   STACK

Metals In Pumpable Wastes

Metals In Non-Pumpable Wastes

Vapors

Vapors

Coarse Fly Ash

Fine Fly Ash (Condensed Vapors)

Residual Vapors

Coarse Fly Ash

Slag

Residual Solids

Wet Scrubber Effluent

External Review Draft

IV. FUGITIVE EMISSIONS

A. Potential Emission Sources

During normal operations, atmospheric emissions may occur from a variety of sources other than the incinerator stack. These releases, which are collectively termed "fugitive" emissions in this risk assessment, typically involve waste unloading, processing and storage, and the handling of ash generated by the incinerator. Potentially significant fugitive emission sources at the WTI facility are identified based on information in the WTI facility permit application (WTI 1982), the facility permit (U.S. EPA 1983), an evaluation of the types of waste handled at each stage of facility operations, and a facility site visit. Through this process, five potentially significant fugitive emission sources are identified at the WTI facility for evaluation in the risk assessment:

- The carbon adsorption bed (CAB) system, which receives organic vapors vented from tanks in the organic waste tank farm, from operations in the container processing building, and other potential sources of fugitive organic compound emissions. Vapors from the storage tanks are collected and vented to the incinerator when it is operating, and to the CAB when the incinerator is not operating. Emissions from the container processing building may result from such activities as sampling of waste-containing drums, puncturing of drums prior to incineration and pumping of liquids from drums. Fugitive emissions within the container processing building are collected via localized hoods and vented to the incinerator when it is operating, and to the CAB when the incinerator is not operating.

- Seals, valves, and flanges associated with storage and process tanks inside the organic waste tank farm building. Although WTI has a program in place to detect and repair leaking valves and flanges (WTI 1982), some leaking may be expected over the life of the facility.

- The wastewater holding tank that collects storm water runoff from process areas within the facility. There are three different wastewater systems at WTI: A, B, and C. System "A" collects non-contaminated storm water from such areas as roofs and the employee parking lot, and the water is discharged directly to the Ohio River.

System "B" collects storm water from "nonactive" process areas such as sumps and plant roadways where contamination is possible but not normally expected. "B" water is retained in three 200,000-gallon tanks and is tested prior to discharge. System "C" collects water from active process areas such as diked tank areas, washdowns, and other areas where some contact with hazardous waste can . reasonably be expected. "C" water is stored in one 250,000-gallon, open-top tank prior to treatment. This tank may be a source of fugitive emissions.

- The on-site truck wash station. The truck wash station is a building covered and enclosed on two sides and open to the atmosphere on the ends. Waste trucks can drive through the building for washing, during which volatile releases may occur. This station is presently used approximately once per calendar year, but could potentially be used more frequently in the future. In the risk assessment, the wash station is assumed to be continuously operated.

- Routine fugitive ash releases which may be associated with the bag filter that is used to control emissions during the loading of flyash from the electrostatic precipitator (ESP) into trucks.

The locations of the four organic vapor emissions sources and the fugitive ash emissions source are shown in Figure IV-1.

B. Substances of Potential Concern in Fugitive Emissions

1. Substances of Potential Concern in Fugitive Organic Vapor Emissions

As discussed in Chapter II of this volume, wastes received at the WTI facility may be either pumpable or non-pumpable. Pumpable wastes typically have the highest volatile content, and thus represent the most significant source of fugitive vapor emissions. The composite pumpable waste stream contains more than 300 chemicals, which are ranked based on estimated annual feed (lbs/year) calculated using the waste profile sheet information. To focus the fugitive emissions analysis on the substances most likely to be present in vapor releases during normal operations, this list is truncated to include only those chemicals with the largest annual volumes (i.e., the chemicals which taken together constitute 90 percent of the total mass of pumpable waste). This value (90 percent) provides an approximate two order of magnitude difference between the compounds with the highest and lowest feed rates on the truncated list. If compounds with feed rates an additional order of magnitude lower were included, this

would result in almost 130 additional compounds, and would account for 99.8 percent of the total pumpable feed. Evaluating over 220 chemicals would not have focused the fugitive emissions assessment to a significant degree. The resulting 96 compounds represent the substances of potential concern for the vapor fugitive emissions analysis, and are shown in Table IV-1.

2. Substances of Potential Concern in Fugitive Ash Emissions

The combustion of waste materials typically results in the production of solid residues (i.e., ash). Fugitive particle emissions may result from the subsequent collection, handling, and disposal of this ash. The solid incinerator residue of greatest concern with respect to fugitive emissions is the flyash, collected by the ESP in the air pollution control system because it is produced in relatively large quantities, generally has a very fine consistency and thus is subject to atmospheric entrainment, and contains potentially hazardous metals (WTI 1995).

Substances of potential concern associated with fugitive flyash emissions are identified based on chemical analyses conducted by WTI (WTI 1995). In 1994, monthly samples of flyash were collected from the ESP at the WTI facility. The samples of flyash were analyzed for 80 volatile and semi-volatile organic compounds, total and amenable cyanide[5], and 9 metals. None of the 80 organic compounds were detected in any of the 12 flyash samples, and thus organic compounds are not identified as substances of potential concern in fugitive ash emissions. The metals that were detected in at least one sample of ash are selected as substances of potential concern and are identified in Table IV-1. None of the 12 samples included detectable levels of all 9 metals. Total cyanide was also detected in the flyash samples, and thus is selected as a substance of potential concern.

C. Development of Fugitive Emission Rates

1. Tank-Related Emissions from the CAB System

Emission rates from the tanks in the tank farm that are vented to the CAB system are estimated using U.S. EPA tank calculation program (TANKS2). The TANKS2 program uses physical/chemical properties of the waste constituents, such as molecular weight, vapor pressure over a range of temperatures, and concentration in the waste, in deriving emission rates. In estimating the overall composite physical/chemical properties

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[5] Amenable cyanide is subject (or amenable) to chlorination, and is the most toxic form of cyanide.

of the entire waste stream, data for the 12 constituents expected to be present in the highest volume as determined from the waste profile for the first year of operation, is used. Thus, waste feed properties are assumed to be reflective of the 12 constituents that comprise approximately 60 percent of the pumpable waste feed. The total waste feed throughput to the tank farm is based on the maximum heat input rate (121 million BTU/hr HHV) of the incinerator (ENSR 1993).

Contributions from the container processing building to the CAB system are based on the estimated number of drums received at the facility ($\approx$45,000/year), the number of drums sampled ($\approx$4,500/year), the number of drums repackaged ($\approx$16,000/year), and the container processing rate (as listed in Appendix III-1). Emissions are assumed to be equivalent to releases from a leaky valve with heavy liquids, and calculated using U.S. EPA emissions factors (U.S. EPA 1992a).

Vapor emissions from the tanks (and the container processing building) are typically vented to the incinerator for combustion, or to the CAB system when the incinerator is not operating. Based on WTI's first year of operation, the incinerator operated 53 percent of the time. It is assumed that the CAB system effectively controls 90 percent of the organic vapor emissions from the tanks and the container processing building, based on average efficiency data that has been compiled for carbon systems (U.S. EPA 1992a).

2. Other Organic Fugitive Emissions

Total emissions from the seals, flanges, and other sources of vapor leaks in the tank farm are estimated by summing emissions from the individual facility components and sources (i.e., pump seals, in-line valves, and flanges) based on emissions factors for these sources (U.S. EPA 1992a). These vapors would be released through four vents on the tank farm building.

Total organic vapor emissions from the wastewater tank are calculated using mass transfer correlations and emission equations developed for wastewater treatment systems (U.S. EPA 1992a). For purposes of these calculations, the design average throughput of 15,000 gal/day from the WTI permit application (WTI 1982) is used. The wastewater tank emission equations require physical/chemical properties data for the chemical substances in the wastewater to develop a total mass emission rate. It is not possible to input chemical-specific parameters for all the substances that may be present in the wastewater; therefore, chemical-specific parameters for toluene are used to represent total VOC behavior. Toluene is selected because it is one of the top ten constituents by weight in the waste feed accepted by the facility based on waste profile sheets maintained by WTI, and because its critical physical/chemical properties are representative of the

other substances received in large quantities in the pumpable wastes. Toluene has a similar molecular weight, vapor pressure, aqueous solubility, and other physical/chemical parameters as other major components in the waste feed. In addition, toluene is the constituent projected to be received in the third largest quantity (4.0% of the pumpable waste); other chemicals projected to be received in large quantities are hydrocarbon, unspecified (16.8%), cresol (5.2%), methyl ethyl ketone (3.5%), methanol (3.1%), and acetone (2.9%). Total organic waste emissions from truck washing are based on emissions factors developed by U.S. EPA (1992a) for releases of heavy and light liquids from valves.

Total organic vapor emission rates for the four sources of fugitive organic emissions are listed in Table IV-2. As shown in Table IV-2, fugitive organic vapor emissions from the tank farm building, wastewater tank, and truck wash are estimated to be 2,126 lbs/yr, 202 lbs/yr, and 9.9 lbs/yr, respectively. The estimated 224 pounds of organic vapor emitted annually from the CAB system are divided among the four types of tanks in the tank farm (i.e., blending, holding, pumpout, and reception) and the container processing building. Of the 224 pounds of emissions from the CAB, the tanks in the tank farm and the container processing building contribute 212 pounds and 12 pounds of organic vapors, respectively.

3. Fugitive Ash Handling Emissions

The flyash generation rate at the WTI facility is estimated to be 5,300 tons per year, based on the estimated flyash generation rate in WTI's permit application (WTI 1982). Actual flyash emissions from calendar year 1994 totaled approximately 4,000 tons (Victorine 1995). Fugitive emissions of flyash from the ESP may occur during transfer of ash into covered trucks prior to disposal. Emissions generated during the loading process are controlled by a fabric filter, with a fraction of the flyash escaping capture as fugitive emissions. An uncontrolled ash emissions factor of 0.107 lb/ton flyash that was empirically developed by Midwest Research Institute (Muleski et al. 1986) from field testing a coal-fired power plant equipped with an ESP is used, assuming that the flyash from coal burning and hazardous waste combustion are similar. This empirical emissions factor, however, is developed for flyash with an average moisture content of 29 percent (moisture was added to the flyash for control). Since the flyash at WTI would be expected to have a negligible moisture content (due to its temperature above the boiling point of water and the absence of moisture addition), the emissions factor is increased by a factor of ten to 1.07 lb/ton based on the assumed relationship between water content and erodibility. In addition, it is assumed that the control efficiency of the fabric filter that controls emissions during truck loading would reduce the uncontrolled

emissions by 99.5 percent (U.S. EPA 1992a). The resulting ash emission rate based on these factors is estimated to be 28 lb/yr.

D. Key Assumptions for Fugitive Emissions

The key assumptions used in analyzing fugitive emissions at the WTI facility are summarized in Table IV-3. This table indicates the basis for the assumptions listed, the estimated relative magnitude of the assumptions' effect on the overall risk assessment, and the direction of the effect, if known. These assumptions are further discussed in Chapter V of this report.
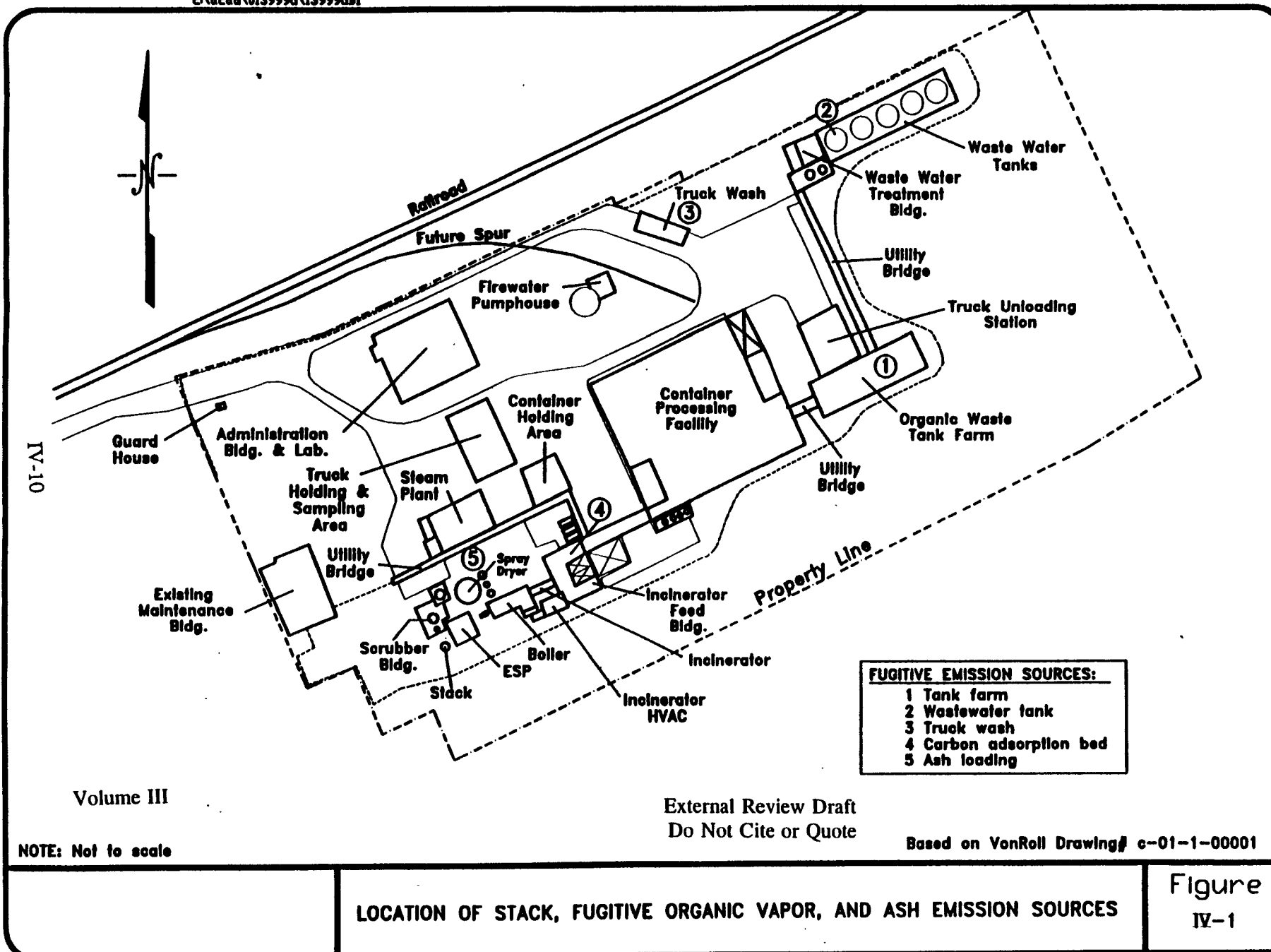
TABLE IV-1
Fugitive Substances of Potential Concern

Fugitive Organic Vapor Emissions[a]

Acetone	Dichlorobenzene	Methyl methacrylate
Acetonitrile	Dichlorodifluoroethane	Methylbutadiene, 1-
Acetophenone	Dichlorodifluoromethane	Methylcholanthrene, 3-
Acetylaminofluorene, 2-	Dichloroethane, 1,1-	Methyl isobutyl ketone
Acrylonitrile	Dichloroethene	Naphthalene
Alcohols	Diethyl stilbestrol	Naphthylamine, 1-
Aliphatic hydrocarbons	Diethylphthalate	Naphthylamine, 2-
Aniline	Dimethyl sulfate	Nitrobenzene
Benzene	Dimethylamine	Nitrophenol, 4-
Benzenedicarboxylic acid, 1,2-	Dimethylbenzidine, 3,3'-	Nitropropane, 2-
Benzidine	Dimethylhydrazine	N-nitrosodiethanolamine
Benzoquinone, p-	Dimethylphenol, 2,6-	N-nitrosodiethylamine
Benzo(a)pyrene	Dimethylphthalate	N-nitrosodi-n-butylamine
Butanol	Dinitrotoluene	N-nitrosopyrolidine
Butanone, 2-	Dioxane, 1,4-	Phenol
Butyl acetate	Epichlorohydrin	Phthalic anhydride
Calcium chromate	Ethanol	Picoline, 2-
Carbon	Ethoxyethanol, 2-	Pyridine
Carbon disulfide	Ethyl acrylate	Resorcinol
Carbon tetrachloride	Ethylbenzene	Tetrachlorobenzene, 1,2,4,5-
Chlorobenzene	Fluoranthene	Tetrachloroethane, 1,1,1,2-
Chloroform	Formaldehyde	Tetrachloroethene
Chlorinated paraffin, oil, wax	Formic acid	Tetrahydofuran
Chrysene	Furfural	Toluene
Creosote (coal tar)	Heptane	Toluene diisocyanate
Cresol	Hydrazine	Toluenediamine
Crotonaldehyde	Indeno(1,2,3-cd)pyrene	Trichloro-1,2,2,-TFE, 1,1,2-
Cumene	Isobutanol	Trichlorobenzene
Cyclohexane	Isopropanol	Trichloroethane, 1,1,1-
Cyclohexanone	Isosafrole	Trichloroethene
Dibenz(a,h)anthracene	Maleic anhydride	Trichlorofluoromethane
Dibromoethane, 1,2-	Methanol	Xylene

Fugitive Ash Emissions[b]

Arsenic	Nickel
Barium	Selenium
Cadmium	Silver
Lead	Cyanide

Notes:

[a] Developed from list of "pumpable" waste streams handled by WTI during first year of operation. These substances represent approximately 90 percent of the total pumpable waste stream. Pumpable waste stream constituents list developed as described in Appendix III-1.

[b] Based on metals detected in fly ash samples collected by WTI (1995).

TFE - trifluoroethane

TABLE IV-2	
Estimated Total Fugitive Organic Vapor Emissions Rates	
Source	**Estimated Emissions lb/yr (g/sec)**
Tank Farm Building[a]	2,126 (3.06×10^{-2})
Wastewater Tank	202 (2.91×10^{-3})
Truck Wash Building	9.9 (1.42×10^{-4})
Carbon Adsorption Bed System (total)	224.3 (3.23×10^{-3})
From Tanks:	212.2 (3.06×10^{-3})
Blending	57.2 (8.23×10^{-4})
Holding	57.2 (8.23×10^{-4})
Pumpout	47.7 (6.86×10^{-4})
Reception	50.1 (7.21×10^{-4})
From Container Processing	12.1 (1.74×10^{-4})
Total All Sources:	2,562 (3.68×10^{-2})

Note:

[a]   Tank farm building emissions are from the leaky valves and flanges which, for the purposes of this risk assessment, are assumed to all occur from the vents on the roof of this building.

TABLE IV-3
Key Assumptions for Chapter IV

Assumption	Basis	Magnitude of Effect	Direction of Effect
All fugitive chemicals of potential concern have been identified and included, even though the list is limited to pumpable wastes (e.g., nonpumpable waste may also be a source of fugitive emissions).	Non-pumpable wastes are handled separately from pumpable wastes and because they are generally not volatile, they are not likely to result in fugitive emissions.	low	underestimate
The composite liquid waste stream list is truncated to include only the chemicals in the top 90% by mass.	Simplifying assumption to focus assessment.	low	underestimate
All fugitive emission sources have been identified.	A site inspection was conducted to identify all significant sources of fugitive emissions.	low	underestimate
The 12 monthly flyash samples used to determine the fugitive chemicals of concern and amounts are representative of actual conditions. Because organic compounds were not detected in these samples, they are not considered. Additionally, the chemicals on the analyte list include all the chemicals that are likely to be present.	Best available data.	low	underestimate
The same chemical composition is used for all fugitive sources.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
The contributions to the CAB system are based on the estimated number of drums received at the facility, the number of drums sampled and repackaged, and the container processing rate.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
Emissions from the CAB system are estimated as equivalent to releases from a leaky valve with heavy liquids using appropriate emission factors.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
The wastewater tank is treated as a non-aerated sump using a default wind speed and an average throughput. Toluene is used as a surrogate for VOC behavior.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
Emissions from the truck wash are equal to releases of heavy and light liquids from valves.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
The emissions factor for flyash from coal burning is applied to incinerator flyash emissions but increased by a factor of 10 because of negligible moisture content.	Professional judgment based on relationship between water content and erodibility.	low	unknown

—N—

Railroad

Future Spur

Truck Wash ③

Firewater Pumphouse

② Waste Water Tanks

Waste Water Treatment Bldg.

Utility Bridge

Truck Unloading Station

① Organic Waste Tank Farm

Container Processing Facility

Container Holding Area

Utility Bridge

Guard House

Administration Bldg. & Lab.

Truck Holding & Sampling Area

Steam Plant

④

Incinerator Feed Bldg.

Organic Waste Tank Farm

Utility Bridge

Existing Maintenance Bldg.

⑤ Spray Dryer

Scrubber Bldg.

Boiler

ESP

Incinerator

Stack

Incinerator HVAC

Property Line

IV-10

FUGITIVE EMISSION SOURCES:
1 Tank farm
2 Wastewater tank
3 Truck wash
4 Carbon adsorption bed
5 Ash loading

Volume III

External Review Draft
Do Not Cite or Quote

NOTE: Not to scale

Based on VonRoll Drawing# c-01-1-00001

LOCATION OF STACK, FUGITIVE ORGANIC VAPOR, AND ASH EMISSION SOURCES

Figure
IV-1

V. UNCERTAINTY IN EMISSIONS CHARACTERIZATION

As previously discussed in this volume, an important initial step in the risk assessment is estimating emissions from both the incinerator stack and fugitive sources. To reduce uncertainty in estimating incinerator emissions, a comprehensive stack testing program was performed at the WTI facility. However, variabilities in the stack testing results and waste feed composition must still be taken into account in evaluating the results of the stack test. Furthermore, predictive models, some with potentially significant uncertainties, are used to supplement the stack testing, and also as the basis for predicting fugitive emission rates. The primary sources of uncertainty associated with the emissions characterization are described in the following sections.

A. Uncertainties in Stack Emissions Characterization

The primary uncertainties associated with stack measurements from the WTI facility are associated with the sampling and analytical techniques, which are subject to rigorous quality assurance/quality control procedures, and differences between the waste feed during the tests and waste feeds that might be received during long-term operation. Changes in facility design or operation may also result in emissions which differ significantly from those observed during facility tests.

Sampling and analysis uncertainty is relatively small given the rigorous quality assurance/quality control procedures employed during the testing at WTI. Some of the variability and uncertainty in the stack testing has also been captured by repetitive sampling that has been conducted as part of the quarterly performance test during which the constituents of primary concern, PCDD/PCDF, have been measured.

Variability in both metal and organic emissions can occur as a result of changes in operating conditions of the incinerator (e.g., kiln temperature). However, the trial burns have been conducted to provide conservative measures of emissions. Emissions of metals are generally more sensitive to relatively small changes in incinerator operating conditions; consequently, the following sections provide a summary of the sensitivity of metal emissions to several incinerator parameters.

1. Uncertainty Associated with Metal Emissions

Although stack testing performed at the WTI facility reduces the uncertainty associated with estimated metal removal rates, the variability in metal feed rates remains an important source of uncertainty. Furthermore, it is necessary to extrapolate SRE data from the seven metals tested in the WTI trial burn (antimony, arsenic, beryllium, cadmium, chromium, lead, and mercury) to eight metals not included in the trial burn (aluminum, barium, copper, nickel, selenium, silver, thallium, and zinc.) The uncertainty of such extrapolation is reduced through thermodynamic modeling performed to better understand metal behavior in the incinerator. The assumptions used in the modeling exercise, and sensitivity of the model to the various input parameters, are described below.

The modeling reflects the current state of the art for understanding metals behavior in waste incineration systems. However, several assumptions inherent in the model fundamentally limit its capability to precisely predict metal emissions. Some of the most important limiting assumptions are:

- <u>Thermodynamic equilibrium is maintained throughout the incinerator and flue gas cleaning system</u>. This assumption is required because in most cases, the needed reaction rates are not known. However, in some cases it is clear that equilibrium is not maintained. For example, the equilibrium model predicts that at ambient conditions, nearly all chromium present with chlorine will form a volatile hexavalent compound. However, field measurements confirm that little chromium is present in the stack as hexavalent chromium. The discrepancy probably arises because the rate of formation of the hexavalent form of chromium becomes very slow at lower temperatures. In this example, the equilibrium model prediction that all chromium is present in the hexavalent form is conservative because hexavalent chromium is more toxic than other ionic forms of chromium. It is possible, however, that assuming equilibrium conditions is not conservative for all metals.

- <u>The formation of metal complexes will not significantly affect metal emissions</u>. Complex reactions between ash components and certain metals are possible. The complexes that form may have different volatilities than other forms of the metal, and are not generally present in the thermodynamic data base used in the model. The potential effects of these complex reactions on predicted emission rates are unknown.

- **The reactor outlet temperature adequately characterizes the temperature to which the metals are exposed.** The temperatures in the incinerator vary significantly, and the behavior of the metals, as demonstrated by the sensitivity analysis described in the Appendix III-1, can be strongly influenced by temperature. However, for most metals of concern, no change in behavior is expected within the typical temperature range of the WTI incineration system.

These assumptions introduce unquantifiable uncertainties, but are believed to be appropriate given the base of information available. Stack testing from the WTI facility suggests that the metal emission rates developed for the risk assessment are representative, and are consistent with theoretical modeling considerations.

It is possible to evaluate the impact of variations in the input parameters used by the model on the predicted emissions. Site-specific input parameters include such data as combustion chamber temperature and waste feed composition. General, non-site-specific information includes thermodynamic data, gas viscosities, and similar parameters. The non-site-specific data are generally more precisely known than the site-specific data, and thus are believed to be less likely to contribute significantly to the overall uncertainty in the predictions. Because of this, a sensitivity analysis is performed to evaluate the impact of variations in site-specific input parameters. The following site-specific parameters are used in the model:

- Waste composition and feed rate
  - Chlorine
  - Trace metals
- Incinerator system conditions
  - Temperature
  - Availability of oxygen
  - Entrainment
  - Quench temperature
- Control device efficiency
  - Vapors
  - Fine Particles
  - Coarse Particles

The effects of reasonable variations in waste feed rate, combustion chamber temperature, availability of oxygen, waste chlorine concentration, quench temperature and entrainment rates are examined in Appendix III-1. With the exception of waste feed rate, each of these parameters will affect the behavior of only a few of the metals. However, the impact on the metals affected can result in changes in emission rates of more than an order of magnitude, as discussed below.

a) **Waste Composition and Feed Rate**

Three feed rates are examined for each of the 15 metals in the sensitivity analysis:

- Base case (maximized heat input feed rates)
- High feed rate (one order of magnitude higher than base case)
- Low feed rate (one order of magnitude lower than base case)

When the feed rates of all of the metals of interest are varied by an order of magnitude, emission rates change proportionately for each metal, indicating that this variable has a strong impact on predicted emission rates (with the predicted system removal efficiencies remaining constant).

b) **Conditions in Incinerator System**

Four combustion chamber temperatures are examined -- 1,000°C, 1,100°C, 1,200°C and 1,400°C. A temperature of 1,200°C is used as the base case. These temperatures represent an approximate maximum variation possible during sustained operation given the physical constraints of the system. Of the 15 metals examined, only the emissions of beryllium, copper and nickel are affected by the change in temperature. At the two lower temperatures, no beryllium vaporizes in the combustion chamber. The emissions decrease from 1×10^{-7} g/s in the base case to less than 1×10^{-8} g/s at the two lower temperatures. Vaporization of copper and nickel is reduced at 1,000°C. The emissions of both of these metals is approximately one order of magnitude lower at 1,000°C than at any of the other temperatures. At the higher temperatures, beryllium, copper and nickel are predicted to vaporize and condense forming fine particles. At the lower temperatures, the metals will remain with the ash.

To assess the affect of the availability of oxygen on the predicted metals behavior, the effects of two additional values of the primary chamber air to waste stoichiometric ratio are examined. In general, varying the stoichiometry of a

combustion system for values around 1.0 has the greatest impact on emission rates. As the ratio moves away from 1.0, the incremental effects observed with additional changes in the value decrease dramatically. Typically, most of the variation occurs between values of 0.8 and 1.2. Thus, the effect of these two values of stoichiometric ratio on emission rates is examined.

At the lower oxygen concentration, the vaporization of beryllium is lower than in the base case due to the formation of reduced forms that are less volatile than the oxide. The predicted beryllium emissions are approximately one order of magnitude lower when the stoichiometric ratio is 0.8 than when it was 1.0. The predicted nickel emissions are about one order of magnitude lower when a stoichiometric ratio of 1.2 is used.

The impact of chlorine is examined. Emissions are predicted for a waste that does not contain chlorine and the results are compared with the maximum heat input case. Copper, nickel, and selenium are affected by the removal of all chlorine from the system. In the absence of chlorine, copper and nickel no longer vaporize in the primary combustion chamber. When the vaporization in the primary chamber is eliminated, the emissions drop by about one order of magnitude. Selenium, in contrast, still vaporizes in the primary chamber when no chlorine is present. However, the vapors will condense in the quench if there is no chlorine present. This results in a decrease in emissions by about an order of magnitude.

Quench temperature can have a strong effect on the behavior of some metals. To quantify this impact and identify the metals influenced most significantly by the quench temperature, two temperatures in addition to the base value of 150°C are examined. While it is unlikely that lower temperatures could be achieved, higher temperatures may result from system failures or operator errors. Thus, 200° and 400°C are selected because they best illustrate the impact of quench temperature on the behavior of the metals of interest. It is extremely unlikely that the system would ever operate at these higher temperatures for any extended time. Cadmium, antimony, thallium, and zinc are affected by the quench temperature. As the temperature increases, condensation of these metals decreases. Emissions increase correspondingly due to the low capture efficiency for vapors. Thallium emissions are one order of magnitude higher than the base case for both of the higher quench temperatures. Zinc and cadmium emissions are one order of magnitude higher than the base case at 400°C only. Antimony emissions are slightly higher than the base case at the highest quench temperature.

The final parameters examined are the entrainment rates. The following values are selected to represent reasonable extremes based on facility design and operation:

- A reduction of the entrainment of the ash in the pumpable wastes by 50 percent; and

- An increase in the entrainment of the ash in the non-pumpable wastes by 50 percent.

Decreasing the entrainment of ash in the pumpable waste is found to result in a decrease in emission rates for aluminum and chromium while the rates for other metals are unchanged. Increasing the entrainment of the ash in the non-pumpable waste causes a small increase in emissions for chromium and aluminum.

c) Control Device Efficiency

The uncertainty in the predicted removal efficiencies can be estimated by calculating the standard deviation observed during the three test runs conducted during the trial burn. Table V-1 summarizes the control efficiencies used and the associated standard deviations. Because the control efficiencies are estimated using data obtained during the trial burn in a series of tests repeated over a short time using a well controlled simulated waste, it is likely that the values in Table V-1 represent the smallest possible variability. In operation over long time periods, it is likely that the variation in waste composition, emission values, and perhaps control efficiencies would be much greater.

d) Results of Sensitivity Analysis

Based on the values in Table V-1 and the sensitivity study, it is possible to determine the potential range of variation that may be expected in the predicted emission rates. Table V-2 summarizes this analysis. The minimum value is produced by using the model to predict emissions when all the data are at the values which produce the lowest predicted emissions. Thus, this prediction uses the lowest reasonable entrainment rates, primary chamber temperature, quench temperature, chlorine concentration, and metals feed rates. The impact of oxygen concentration is relatively small and is not included in this analysis. In addition, the control efficiency is assumed to be greater by one standard deviation than the average from the March 1993 trial burn. One standard deviation is selected as sufficiently representative of the probability variations in the control efficiencies. Variations in control efficiencies are very small compared to the possible variations in other parameters such as metals feed rates and have little impact on this analysis. The maximum value is obtained using a similar technique. The highest reasonable entrainment rates, primary chamber temperature, quench temperature, chlorine

concentration, and metals feed rates are used simultaneously. The control efficiencies are assumed to be less by one standard deviation than the 1993 trial burn averages.

Variation in the feed rate accounts for most of the variation observed in the predicted emission rates for each metal. For this analysis, it is assumed that actual feed rates could deviate from the maximum heat input feed rate by as much as an order of magnitude, based on the following observations:

- The concentration information in the data base used to determine the waste composition is generally based on the results of a single analysis of the waste. Trace metals concentrations in wastes typically vary widely.

- The data base incorporates many assumptions about the type and quantity of the wastes which would be available for incineration.

- Normalization and other data processing is required to place all data on a common basis. Such processing adds potential sources of variation.

Because metal emissions from hazardous waste incinerators are very dependent on the site-specific feed rates of those metals, feed rate limits are generally established under operating permits to control maximum emissions. Permit limits can be used, where necessary, to restrict the upper bound of the metal emission rates and hence limit the impact of this kind of uncertainty.

It should be emphasized that modeling of the behavior of metals in waste incinerators is still very approximate. Current models are best used for predicting trends and estimating the impact of changing operating conditions. They are not as successful at precisely predicting metal emission rates. Furthermore, the model is capable of predicting metal species present in emissions and predicting the phase of each metal emitted, as shown in Appendix III-1. However, the results of this modeling exercise are not used in the risk assessment to predict specific metal species or phases given the high degree of uncertainty in the model results.

2. Uncertainties Due to Uncharacterized Stack Emissions

Stack gas samples collected during the trial burn and performance tests were analyzed for a list of conventional analytes. A fraction of the sample may contain organic compounds such as methane and ethane, or other aliphatic or aromatic hydrocarbons, which are not conventional analytes. This fraction has been termed the

"uncharacterized fraction." In some cases, the uncharacterized, non-methane portion of the emissions may be considerably larger than the characterized fraction. In the absence of any information on the fate and transport characteristics or toxicity of these unknown compounds, there is some uncertainty in the risk assessment associated with the incomplete characterization of emissions from the stack.

For the purposes of uncertainty analysis in the risk assessment, the amount of organic emissions that might not have been measured is estimated using the following procedure. First, the recorded total hydrocarbon (THC) stack emission levels from the March 1993 trial burn are evaluated and adjusted upward (by a factor of 2.87) to account for the fact that THC analyzers typically underestimate organic emissions (U.S. EPA 1988a). As discussed in Appendix III-1, the following factors account for the understatement of THC measurements: (1) organics potentially condense in the sampling line moisture trap; and (2) several compounds are biased low by the flame ionization detector within the THC analyzer. A correction is also required to account for the difference in molecular weight between the calibrating gas, methane, and the actual average molecular weights of the organic emissions. Taking these factors into consideration, the resulting adjusted THC value is a measure of the "total organics" in the combustion stream.

The adjusted THC value is then compared to the total characterized fraction PIC emissions, as described in Appendix III-1. The comparison of the characterized fraction organic emissions to the adjusted THC indicates that an estimated 60% of the non-PCDD/PCDF PIC emissions could potentially remain uncharacterized. Thus, non-PCDD/PCDF PIC emissions from the incinerator could potentially be as much as 2.5 times the measured amounts.

Within the uncharacterized fraction of the THC, it is possible that various halogenated dioxins and furans may be present. Stack testing conducted during performance tests at the WTI facility has focused on emissions of PCDD/PCDF, i.e., the chlorinated dioxins and furans. There is evidence in the literature that brominated dioxins and furans could have comparable toxicities to the chlorinated dioxins and furans (Mason et al. 1987). However, it is anticipated that only a small fraction of the dioxins and furans emitted from the WTI incinerator stack will be brominated, because a review of the waste feed profile from the first year of operations indicates that less than five percent of the halogenated wastes are brominated. Other halogenated dioxins and furans would be expected to pose a lower risk than either the chlorinated or brominated forms, based on toxicity and waste feed composition.

In the uncertainty analysis of the risk assessment, the emission rate for PCDD/PCDF is multiplied by a factor of 1.5 to conservatively account for brominated

dioxin-like compounds. This factor is believed to be conservative because brominated waste is much less prevalent than chlorinated waste at WTI. It should be recognized that the factor of 1.5 is based primarily on professional judgment, rather than any specific data.

3. Uncertainties Associated with Chromium

The oxidation state of chromium can be a critical issue in characterizing metal emissions in a risk assessment. Chromium compounds can exist in any of three oxidation states: elemental, trivalent, or hexavalent. The toxicity of chromium varies considerably from one form to another. Hexavalent chromium is the most hazardous form of chromium based on its carcinogenic potential. In contrast, elemental chromium and trivalent chromium have not been shown to be carcinogenic in either humans or laboratory animals. Incinerator test results suggest that chromium can exist in more than one of the oxidation states in stack emissions (U.S. EPA 1990a).

The importance of hexavalent chromium is considered in U.S. EPA's proposed rules for owners and operators of hazardous waste incinerators (U.S. EPA 1990b). Although U.S. EPA states in the proposed rules that both the hexavalent and trivalent forms of chromium are expected to be present in incinerator flue gas, the worst-case assumption, that 100 percent of the chromium present in the flue gas is in the hexavalent form, is adopted in this risk assessment.

4. Uncertainties Associated with Laboratory Contamination

The possibility of laboratory contaminants must be considered when evaluating analytical results, especially for common laboratory contaminants, such as phthalates (ATSDR 1993). In this assessment, six phthalate compounds are considered as substances of potential concern, including bis(2-ethylhexyl)phthalate, butylbenzylphthalate, diethylphthlate, dimethylphthalate, di-n-butylphthalate, and di-n-octylphthalate. The presence of these compounds has been documented in many types of laboratory equipment, including plastic tubing, plastic gloves, rubber, and teflon sheets (U.S. EPA 1988b; Giam et al. 1975), and can lead to the contamination of environmental samples. While efforts are generally made to reduce laboratory contamination by thorough cleaning, phthalates are often reported in many laboratory blanks (Thuren 1986; U.S. EPA 1988b). Consequently, U.S. EPA (1988b) has reported that common phthalate esters generally can not be precisely measured at concentrations below 2 ppb due to blank contamination.

B. Uncertainties Introduced by Process Upset Emissions

As discussed in Appendix III-1, a variety of process upsets may be expected during normal operation of the WTI facility. However, potential process upset emissions are not included in the risk assessment calculations due to: (1) the significant uncertainties associated with characterizing emissions during these short-duration events; (2) the expectation that the magnitude and duration of such potential emissions would be quite limited; and (3) the measures in place at WTI to reduce the frequency and impact of such emissions. As discussed below, several different situations have been identified that could lead to process upset emissions, although the magnitude of these releases is not anticipated to be significant when compared to routine facility emissions or releases during the types of accidents evaluated in Volume VII.

- **Plant Startup.** The RCRA permit for the WTI facility prohibits injection of hazardous waste to the incinerator until the kiln reaches the minimum temperature demonstrated during the trial burn, and until the incinerator is within the operating envelope defined by the permit. Therefore, wastes can not legally be introduced until the incinerator is within the complying operating conditions. Similarly, planned shutdowns would involve shutting off waste feed and properly burning out residue before termination of incinerator operation. However, unplanned shutdowns can occur; some of the potential problems associated with these conditions are discussed below.

- **Emergency Vent Stack Releases.** Unlike most rotary kiln incinerators, the WTI facility does not have an emergency relief vent stack. Instead, an automatically activated emergency electrical generator allows continued operation of the induced draft (ID) fan (albeit at a lower speed) and all major pumps in the event of a complete electrical power failure. Therefore, no emergency vent stack emissions are anticipated.

- **Interruptions in Water Supply to the Scrubber System.** The packed bed and venturi scrubbers installed at the WTI facility are used both for HCl control and additional fine particle control (note that the scrubbers follow a 3-stage ESP which collects most of the particles). The scrubber system would not be expected to contribute significantly to the control of organics emissions, but might have a minor impact on emissions of those organics which are adsorbed onto the surface of the activated carbon injected into the duct work. Therefore, failure of water supply to

the scrubber would not be expected to have a significant impact on organics emissions.

Under the RCRA permit for the WTI facility, any failure of the scrubber system would trigger an instantaneous automatic waste feed cutoff. Pumpable wastes would rapidly cease burning and therefore no longer represent a source of emissions. Solid-form wastes, such as drummed wastes and bulk wastes, may continue to burn in the kiln for several minutes (up to perhaps 30 minutes). Therefore, any assessment of potential emissions after an unplanned waste feed cut-off would need to consider the potential emissions generated by solid-form wastes which may have been charged into the incinerator immediately prior to the process upset event.

Because solid-form wastes are not atomized but, rather, are burned in a more quiescent manner, these wastes would not be expected to generate as high a particle loading in the gas stream or liberate as great a quantity of metals (if the waste contained metals) as the pumpable wastes. This is because: (1) the atomized liquid wastes generally are better dispersed and have more surface area available to absorb heat, vaporize metals, and then transfer metals to the gas stream; and (2) atomization tends to mechanically generate a considerable amount of particulate matter, as well as generate more vapors which can subsequently condense/nucleate into particulate matter. In addition, atomization more vigorously disperses both of these types of particulate matter in the combustion stream. Furthermore, since the vast majority of the mass flow of particle emissions is caught in the ESP and not in the scrubber, even complete failure of the wet scrubber system would not be expected to increase overall particle emissions dramatically.

Volatile metals emissions may also be partially collected in the wet scrubber system; therefore, emissions of such metals might be expected to rise slightly for the first 5 to 30 minutes of a scrubber water failure event, if 1) solid-form waste continued to burn in the kiln after a scrubber failure, 2) the solid waste happened to contain a significant quantity of volatile metal(s), and 3) the metal species were predominantly in a soluble vapor form. But since solid-form wastes generally liberate considerably less of their volatile metals than do pumpable wastes, and since solid-form wastes are not the majority of total wastes at WTI, this scenario is not expected to create the potential for a significant additional source of volatile metals emissions.

Because the scrubber vessel is rubber-lined, failure of water cooling could cause the rubber liner and plastic bed media to melt and be destroyed by the hot combustion gases. Accordingly, WTI has designed several levels of redundancy into the quench/scrubber water supply system to prevent such a scenario. Because of this redundancy, complete failure of water supply to the quench/scrubber is considered to be an infrequent event.

In summary, because of the low expected frequency of such a scrubber water failure, because of the nature of the waste combustion, and because of the relatively minor reduction in overall control efficiency expected during a scrubber water failure, this type of event is unlikely to significantly affect overall facility emissions.

- **Interruptions in Air Flow.** An ID fan operates in the incineration train prior to entry of flue gases into the stack. Fan failure due to catastrophic mechanical failure or due to power failure would be expected to result in positive pressure in the combustion chamber. Pumpable wastes would be cut off immediately and would not create, therefore, any further emissions. If solid waste had been charged to the kiln shortly before such an event, partially burned organics could be emitted through the kiln seals, since this would generally be the path of least resistance to the atmosphere once the kiln is under positive pressure.

As mentioned earlier, power failure at the WTI facility does not necessarily result in complete loss of the ID fan. An emergency 1,000 KW generator is present as backup in the event of a power failure, and this generator can keep the ID fan running, although at reduced speed, to keep the system under negative pressure.

In spite of this back-up system, a fan-related release did occur in December of 1993 when a software logic error caused a complete fan shut-off after a quench water feed system failure. Although the water supply was, in fact, maintained to the quench unit via backup, the control system shut off the ID fan. During that event, the operators reported that visible emissions (taken to be an indication of particle emissions and perhaps emissions of unburned organic chemicals) were observed from the kiln seals for three to five minutes.

On October 31, 1994, kiln gases were again accidentally released for up to ten minutes. This event was also reportedly caused by a software logic error. In this case, the control system incorrectly interpreted a blown fuse as an indication that the

waste heat boiler had gone dry. This tripped the ID fan motor circuit completely off, and the operators were not able to quickly override the automatic control system to get it running again. In this instance, the kiln gases escaped by flowing backwards through the vapor recovery system piping, rupturing a section of flexible piping, and escaping through the rupture.

In response to these events, WTI has taken measures, including computer logic changes and the addition of manual overrides, to eliminate situations such as these and others which might result in the ID fan completely tripping off. Under these circumstances, releases from interruptions in air flow are anticipated to be infrequent events.

- **Kiln Overpressure Events.** Events which cause the kiln to "overpressure," that is, to be held at higher than atmospheric pressure for more than a few seconds can result in the release of partially burned waste material through the kiln seals. Kiln overpressures may be caused by chunks of solidified ash, or clinker, falling into the slag quench tank, which is located directly beneath the secondary combustion chamber. This causes a sudden release of steam to travel back into the secondary combustion chamber, causing an overpressure event. An overpressure event of this nature is less likely to cause a release of waste constituents than an event associated with a feed or waste flow anomaly, since a steam-related overpressure is most likely to release steam to the atmosphere. An example of a waste flow anomaly is the intermittent charging of containerized high BTU solid and liquid wastes in a batch mode that can cause temperature and pressure excursions.

Kiln overpressure events trigger automatic waste feed cutoffs (AWFCOs); consequently, as described earlier, emissions associated with these events are not expected to occur over extended durations. Nevertheless, due to the frequent occurrence of kiln overpressures (WTI 1994), a detailed evaluation of these events has been conducted as described in Appendix III-1.

The analysis of AWFCOs conducted as part of this risk assessment, and described in the Appendix of this report, does not identify reliable estimation techniques or empirical studies quantifying the nature or magnitude of emissions from overpressure releases in the scientific literature. However, since these emissions occur from the kiln seals, PCDD/PCDF are unlikely to be associated with these releases given current understanding of the conditions conducive to PCDD/PCDF

formation. PCDD/PCDF formation is maximized in the post-combustion zone of the incinerator if the flue gases are allowed to reside at temperatures of 450° to 750°F.

In summary, emissions from AWFCOs associated with kiln overpressures are difficult to estimate, but are unlikely to contain significant concentrations of dioxins and furans. Nevertheless, the inability to quantify emissions associated with frequent AWFCO events results in some uncertainty in the risk assessment.

C. Uncertainties in Fugitive Emissions Characterization

The major sources of uncertainty associated with estimation of fugitive emissions from routine storage activities are summarized below:

- The amount of waste handled by the facility on an annual basis;

- Number and type (bulk vs. containers) of truckloads of waste received by the facility;

- Because the pumpable waste stream for the waste profiles data base is used to calculate emissions, all uncertainties associated with the waste profile data base are inherent to these calculations;

- The tank emissions calculation software is based on empirical equations using default values for parameters such as seasonal temperature, wind speed, and meteorological data. Also, since the actual waste handling pattern between tanks may vary greatly depending on the volume of pumpable wastes received and the available storage tanks, it is assumed that the entire volume of pumpable wastes passes through each type of tank once, rather than all tanks sequentially;.

- The relative percent of time the tank and container pumpout emissions are vented to the incinerator vs. the carbon adsorption bed could vary from the 53% to 47% ratio;

- Uncertainty relative to the wastewater tank includes the throughput of stormwater, type and concentration of contaminants in the water (both are dependent on rainfall and spills or leakage of water), and uncertainties associated with the empirical equations used to calculate the emissions;

- For container releases and truck washing, uncertainty is based on number of containers or vehicles processed, type of waste contained, and use of relatively non-specific, generic emission factors to calculate emissions; and

- For fugitive emissions, uncertainty is associated with the number of pumps, flanges, valves and seals that are in operation at any one time, and the use of relatively non-specific emission factors to calculate emissions.

It is believed that there is no general trend in these uncertainties which would result in an over- or underestimation of fugitive emissions.

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TABLE V-1		
Observed Variation in the Control Efficiency of Selected Metals During the May 1993 Trial Burn		
Class of Material	Control Efficiency (percent of weight)	Standard Deviation
Insoluble vapors	6	4
Soluble vapors	99.68	0.2
Fine particles	99.977	0.006
Coarse particles	99.997	0.002

TABLE V-2 Possible Variation in Predicted Metals Emissions Due to Uncertainty in Input Data			
	Predicted Emission Rate (g/s)		
Metal	Based on Most Probable Data	Minimum	Maximum
Aluminum	2.4×10^{-4}	2.2×10^{-6}	5.2×10^{-3}
Barium	1.5×10^{-4}	1.2×10^{-5}	1.9×10^{-3}
Copper	9.4×10^{-5}	1.0×10^{-7}	1.2×10^{-3}
Nickel	5.0×10^{-6}	3.1×10^{-9}	6.3×10^{-5}
Selenium	4.7×10^{-4}	2.6×10^{-6}	4.7×10^{-3}
Silver	1.5×10^{-5}	1.2×10^{-6}	1.9×10^{-4}
Thallium	3.4×10^{-5}	2.6×10^{-6}	4.7×10^{-3}
Zinc	1.2×10^{-4}	9.5×10^{-6}	1.7×10^{-2}

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APPENDIX III-1

EMISSIONS ESTIMATION METHODOLOGY
AND BACKGROUND

APPENDIX III-1

EMISSIONS ESTIMATION METHODOLOGY AND BACKGROUND

C O N T E N T S

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CHAPTER I. INTRODUCTION

A. Scope

This appendix presents estimations of emissions from various activities at the WTI facility in East Liverpool. These estimations are performed in support of the risk assessment at the WTI facility. Emission estimates are performed for metals and organics emissions from the WTI incinerator, and for fugitive emissions from other activities at the site. Subsequent to development of emissions estimates, additional stack testing of PICs were performed. Data from these tests are used in the risk assessment (see Volume III); however, the discussion on emissions estimates is presented to further verify the test data.

B. Concerns to be Addressed

The 1993 Peer Review Panel raised a series of comments regarding the emission characterization section of the original 1993 project plan for the WTI risk assessment (U.S. EPA 1993b). These comments were directed primarily toward characterizing certain types of emissions from the WTI incinerator for which test data did not exist. Additional concerns directed toward organic emissions noted that a potentially large fraction of organic emissions from the incinerator were uncharacterized, and that the waste feed used in the WTI trial burn was not representative of the type of waste normally burned in the incinerator. These concerns called for the development of a chemical composition profile representative of wastes routinely burned at the facility, and the estimation of compound-specific emissions to represent the uncharacterized fraction of organic emissions from the incinerator.

Concerns were also directed towards characterization of metals emissions including defining the emission rates of metals for which there are no test data, identifying the chemical form (speciation) of the metals, and predicting the impact of changes in parameters such as kiln temperature on metals emissions.

Furthermore, concerns were raised about transients due to non-steady state operation, system upsets that could cause a waste feed cutoff, fugitive emissions due to leaks and spills, and catastrophic events such as fires and natural disasters.

C. Approach

The comments summarized above led to the development of an assignment to estimate emissions. The assignment is broken down into four major areas, each described below.

1. **Waste Profile Data Base**

Development of a waste profile data base to represent wastes received or projected to be received by the facility over the course of the first year of operations. The data base, and ultimately two surrogate waste streams representing pumpable and non-pumpable wastes, is developed based on projected waste volumes from individual waste sources. The surrogate waste streams are then used in the estimation of emissions from the other tasks (primarily metals).

2. **Estimation of Metals Emissions**

Estimation of metals emissions that were not measured during tests at the facility, and evaluation of metals control efficiency, particle size distribution, and reentrainment from scrubber water. Conservative estimates of system metals removal efficiencies and metals speciation are developed as part of this task.

3. **Estimation of Organic Emissions**

Estimation of organic emissions representing the unmeasured fraction of emissions from the incinerator. A target list of potential compounds is identified, and a method developed to characterize the unmeasured fraction based on organic analytical data from tests performed at the facility. Subsequent to this exercise, additional stack testing was performed providing the bulk of the data used in the risk assessment.

4. **Estimation of Emissions from Other Activities**

Estimation of frequency of occurrence and emissions from automatic waste feed cutoffs, estimates of fugitive emissions from leaks, spills, and routine waste handling activities at the facility, and estimation of fugitive particulate emissions from ash handling activities at the site are presented in this task.

The assignment is presented in two phases, particularly since the Peer Review Panel had suggested a number of techniques for estimating emissions, and other techniques for estimation were also available. Therefore, the first phase is to evaluate

alternative approaches to complete the assignments and the second phase is to implement the favored approach.

D. Overview of Limitations

As in any estimation technique, there are uncertainties involved with the emissions estimated under this assignment. These uncertainties and key assumptions made in the process will be discussed in greater detail in each of the following sections of this appendix. Many of the limitations encountered are similar, in that they stem from not having complete knowledge or information about wastes fed to the kiln, behavior of the wastes or combustion process within the kiln, or behavior of the combustion gases in the air pollution control system. Still other uncertainties stem from the assumptions made within the estimation techniques, or the use of one technique rather than another. However, the majority of uncertainties should either have minimal impact on the overall calculated risk, or should err on the side of overestimating the risk.

E. Organization

This appendix is organized as follows. Chapter II describes activities relating to the waste profile data base. Chapter III covers estimation of metals. Chapter IV deals with organic estimates, and Chapter V includes activities relating to automatic waste feed cutoffs, waste handling activities, and ash handling. References are included as Chapter VI. Each section contains a description of the peer review comments, approach, emissions estimations, and a discussion of uncertainties. The Attachments to all sections are included following Chapter VI.

CHAPTER II. WASTE PROFILE DATA BASE

A.   Introduction

As an initial step in the emissions analysis, an evaluation is performed of waste feed material. Because materials fed to the incinerator during the initial trial burn may not be representative of a typical waste feed during facility operations, it was suggested that waste manifests from the facility's first year of operation be used to develop a waste feed chemical composition profile. This chapter describes the approach taken to develop the waste profile data base.

B.   Data Base Development

To develop the waste feed profile, it is necessary to evaluate the waste composition of individual incoming waste streams to the facility. Waste manifests, which were a source of data suggested by the Peer Review Panel, list incoming waste by U.S. EPA hazardous waste codes (as defined in 40 CFR Part 261) and were determined to lack appropriate level of detail. Similarly, "fingerprint" analyses performed by WTI at the time of waste receipt provide data important to waste acceptance and handling procedures, but do not provide sufficiently detailed analysis of the chemical composition of the incoming waste stream.

A third alternative source was selected to develop the waste profile data base. The U.S. EPA obtained waste profile sheets for the first nine months of operation at WTI, and waste profile receipt data for the first year of operation. A sample waste profile sheet is included as Attachment 1. Seventy-eight waste profiles are evaluated and entered in the data base. The profiles are completed by the generator prior to any wastes being received by WTI to document the expected composition of waste streams and to receive acceptance approval from WTI. The profiles identify waste composition within expected ranges, physical state of wastes; specific handling instructions and hazardous waste codes. Prior to approving a waste for acceptance, WTI reviews these data to verify the anticipated wastes are within their operating constraints (e.g., permitted conditions). Once a waste is approved by WTI, the profiles are submitted to the Ohio EPA for approval and are subsequently maintained on file to verify incoming wastes. As wastes are shipped to WTI, the manifests are checked against the profiles to determine acceptability of wastes. A quick analysis, often referred to as a fingerprint analysis, is normally performed to verify that the waste is consistent with the waste profile.

To formulate the data base, the waste profiles were first reviewed for content to determine which data were needed. Data selected include: waste profile number (which

identifies the generator), sampling date, annual estimated volume for the waste stream, physical state (i.e., solid, liquid) special handling requirements, constituent content in the form of ranges, and sample analysis results for selected constituents, primarily metals. Paradox™ is used as the spreadsheet software since large amounts of data need to be sorted quickly and because of the ease with which data can be converted to Lotus and Dbase files, should the data need to be manipulated using other software.

Because the waste profiles contain proprietary information regarding the generator and the generator's processes, the waste profile sheets are claimed by WTI as Confidential Business Information (CBI). A unique surrogate waste ID code is used for each waste stream in place of the original WTI source codes, regardless of the number of streams from the same source. The surrogate codes are assigned randomly and are not related in any way to the original WTI source codes. In this way, a detailed nonconfidential master list of the waste streams is created for use in the risk assessment, while the required confidentiality of the generator information is still maintained.

From the waste profiles, three datasets are created as described below:

1.   **Summary Information**

Data from pages 2 & 3 of the waste profile include:

- Surrogate waste code;
- Anticipated annual volume;
- Physical state; and
- Special handling requirements.

2.   **Anticipated Constituent Composition**

Data from pages 4 & 5 of the waste profile include:

- Surrogate waste code;
- Chemical constituents; and
- Range of composition for each constituent (by percent).

3.   **Analysis Results**

Data taken from actual analytical results (page 10 of waste profile) include:

- Surrogate waste code;
- Anions (%s, measured values);
- Metals (measured values); and
- Physical Properties.

The three data sets are cross-linked through the common surrogate code for appropriate linkages as described below.

The anticipated volume, reported in pounds per year are totaled for each source, and the total over a one year period is assumed to be representative. This means that the total wastes for a given source are taken to represent an input rate to the incinerator, from that source, in pounds per year (lbs/yr). The rank of each waste stream is computed based on anticipated volume. The wastes are then sorted by the anticipated volume of each waste stream.

The input, in lbs/yr, from each source, is then divided by the total input volume in lbs/yr to give a percentage of the total input.

After sorting the data base by volume, those sources of wastes which contribute less than 0.5% of the total feed are deleted to streamline the data. This results in a reduction in number of input streams from 78 to 42 (41%) but reduces the total amount of waste volume carried throughout the remainder of the analysis by only 4.45%. The resulting uncertainty due to this reduction is deemed insignificant, and results in a more manageable data base[1].

The second and third WTI data sets, including analytical values, are then appended to the first by the common surrogate codes. This results in the "parent file" for subsequent calculations of constituent feeds and elemental breakdown, as well as a list of waste streams containing multiple packing types and physical states of each stream.

C. General Data Base Refinement

In an effort to evaluate the data base, the various streams in the parent file are analyzed by sorting by volume, percent volume of total, and surrogate codes. The files are then sorted by constituents of each stream. In this analysis, three factors impact the overall usability of the data: 1) the estimation of waste composition by ranges; 2) the nomenclature of identical compounds and the presence of isomers and 3) some analysis results listed are incomplete. Each of these factors are discussed below and steps taken to reduce their impact are described.

1. Estimation of waste composition in ranges.

In the waste profiles, the concentration of the individual components (i.e., constituents) of the waste stream are often estimated as a range. For example, the

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[1] It should be recognized that metal emission rates ultimately used in the risk assessment were prorated up to account for the maximum heat input to the incinerator. Similarly, the annualized volume of each organic compound, whose emissions were estimated using the waste profile data base, was adjusted upwards by a factor of 4.1 to reflect maximum throughput of waste through the incinerator. Thus, the exclusion of certain wastes as discussed above did not significantly affect the emission rates used in the risk assessment.

amount of a constituent in a waste stream might be reported as "1,2-Dichlorobenzene 0-30%". To ensure conservative bias, the upper bound of the percentage range for each constituent is selected as the constituent's concentration. However, this conservative assumption introduced an uncertainty in that waste constituent volumes now totals greater than 100% of the total waste stream volume.

To illustrate this factor, suppose one waste stream contains four constituents. Their estimated concentrations for each constituent is reported as a range of 0-30% of the total waste stream volume. When selecting the upper bound for each constituent, (in this illustration 30% each), the waste stream volume now totals 120% of the original volume.

To account for this factor a prorating method is applied when the total of the upper bounds of estimated ranges is greater than 100%. The upper range value for each constituent is multiplied by the reciprocal of the total. In the example described above, each constituent's upper range value (30%) is multiplied by 100/120 resulting in 25% as the new value. The total for the example waste stream would then be 100% of its input in pounds/year, and each constituent is assumed to be input at 25% of the total input rate for that stream in pounds per year.

In this scheme, each estimate is forced to the highest value possible, while maintaining the ratio of the various constituents of each stream relative to each other. After the prorating is complete, the percentages are totalled and indicated a 1.99% reduction in the total waste volume (possibly due to rounding errors).

The selected prorating method keeps the relative amounts of each constituent constant with each other; however, it introduces a source of uncertainty within the data base. This method ascribes a "point-value" to each constituent to identify a percentage of the waste stream which is then multiplied by the total anticipated annual volume of waste input. The result provides a point value for the volume of each constituent. However, there is no way to determine the actual value of the percentage. Since the waste data represent anticipated annual amounts and thus an average of the total waste feed stream, and the conservative maximum range is applied, the uncertainty introduced by this method is deemed acceptable.

2.   **Nomenclature of identical compounds and the presence of isomers.**
The next level of review identifies several cases of synonyms and isomeric compounds. Since the data originates from multiple sources, different constituent names are utilized to represent the same compound. In the cases of synonyms, the conventional name or IUPAC accepted name is selected. All identical constituents

reported under other names are renamed to the conventional name and summed. The resulting renaming and grouping of isomers under the most commonly used name or IUPAC designation, (followed by an asterisk if renamed) reduces the number of compounds from over 500 to about 320.

An example is one waste source listed methyl benzene as a constituent, and another listed the identical constituent as toluene. Therefore, the methyl benzene is renamed as toluene for consistency. Once this review is performed for all constituents in the parent file, it is re-sorted by name.

Similarly, in the case of isomeric compounds, only the root name is used. An example is the ortho-, meta-, and para- isomers of xylene, which are all renamed "Xylene". The data base is then again sorted alphabetically by name.

3. **Incomplete analysis results.**

Thirteen analysis results listings are incomplete and contain "not analyzed" entries for some analytes or "Not Detected" entries. These entries do not include detection limits or elaborate on testing methods and are entered as values of zero in subsequent calculations.

Upon application of the waste stream data base to the metals analysis (see Chapter III), a further refinement of the data base is necessary. To calculate the molar ratios of elements fed to the incinerator the modeling software requires the waste streams be presented in two discrete waste streams: pumpable and non-pumpable feeds. To create these two waste streams, the wastes are combined by their physical state assigned by the generator. The physical states are reported as one of five types on the waste profile. Wastes reported as Liquid; Liquid, Solid/Liquid Mix and Solid/Liquid Mix are aggregated to create the pumpable waste stream. Those wastes reported as Solid and Solid, Solid/Liquid Mix are aggregated to represent the non-pumpable waste stream. Several inconsistencies are noted at this stage of the data analysis as described below.

- Lithium Batteries—listed in the packaging field as "drummed solids"—are sometimes designated as liquids in physical state field of the original WTI data base. Similarly, several wastes identified as "solid" in the field labeled physical state are identified as bulk liquids in the packaging field. Often, the packaging does not seem to match the physical state. Materials listed as Liquids in the physical state column are also called out as drummed solids, bulk solids, and "other". Materials listed as solids in the physical state field are sometimes listed

as bulk liquids or drummed liquids in the packaging field. For consistency, the simplest field (physical state) is selected when determining the ultimate category (pumpable or non-pumpable) for the waste stream. Since only one physical state is listed for each stream, there could not be any contradiction. Further justification for this approach is the apparent consistency of the reported physical state with the composition of each waste stream. In other words, on a case-by-case examination of the waste streams, the physical state column usually seems reasonable for the type of waste specified and is selected as the primary criterion for pumpability or non-pumpability.

- The molecular formula of one of the listed constituents of one of the streams could not be determined. This compound is listed as "2,3-dibromo-phosphate" and amounts to 462 lbs/yr as estimated before correction for analyte contribution. It is left out of the mass balance. Another compound, listed by confidential trade name, can not be identified in the literature, amounting to 4,604 lb/yr (uncorrected values).

- The data base contains many instances of inputs which can not be accurately speciated; this category is called Miscellaneous ("Misc."). It contains mainly absorbent, dirt, rust, grit, trash, tyvek, debris, sand filter media, personal protective equipment and wood chips. The consequence is an incomplete mass/energy balance. This is a more significant portion of the waste; uncorrected weight in the pumpable stream is nearly one million lb/yr.

- "Ash" percentage is one of the results of analysis of the wastes since ash is often a listed constituent. These values are left out of mass balance calculations, since there is no way to determine the composition of the ash from the data available. No precise number can be attached to the percentage of ash, because it is not measured for all waste streams. Many waste streams listed "NA" for the percentage ash. It is also notable that ash is assumed to be the predominant product of combustion of the Miscellaneous ("Misc.") category of waste.

- Misspellings in constituent names are corrected to the best of our ability. This may lead to misidentification in some isolated cases where different compounds differ only slightly in spelling and no correct choice is evident for a misspelled name.

At this point, each file is sorted by constituent names, and like constituents summed to determine the total amounts of each constituent in each file. The resulting files provide a preliminary estimate for the amounts of individual constituents in each of the pumpable and non-pumpable streams. The data base is further refined by calculating values for the input rates of the individual constituents which both conform to the anticipated chemical composition percentages, and yield amounts of each constituent predicted by the analysis results. The analysis results do not always agree with the amounts of compounds projected in the anticipated chemical composition shown in the waste profile. In order to revise the data to conform to analytical results, the following operations are performed on the data bases:

- Ash (5% of total volume) is deleted from calculations, because it is assumed to be removed by ash handling systems, and since it is primarily a physical parameter rather than a waste constituent;

- The miscellaneous category (3%) is deleted from calculations, since it contains mainly absorbent, dirt, rust, grit, trash, tyvek, debris, sand filter media, personal protective equipment (PPE), and wood chips, for which it is assumed that ash is the primary combustion product;

- The lithium batteries (1%) are deleted from subsequent calculations, since insufficient information existed to properly speciate them; and

- The confidential tradename for which no data are available and "2,3-dibromophosphate" (<1%) are deleted.

These assumptions delete an additional 10% of the volume of waste fed to the incinerators, leaving a total of over 83% of the total volume. The volume (lbs/yr) input columns in each file are totaled excluding water, giving 16,270,747 lbs/yr for the pumpable stream and 5,068,920 lbs/yr for the non-pumpable stream. All subsequent calculations are performed without changing those values, ensuring a "mass-balance". While the exact mix of individual compounds (i.e., relative % of

total volume) fed to the kiln did change, neither the specific compounds nor the total volume in pounds per year change.

The two large data bases (representing the pumpable and non-pumpable waste feed streams) resulting from this approach are treated identically to each other in order to determine their anion and metal contributions. A mass-balance approach is used to assure reasonable agreement between the total mass of wastes known to be fed and the sum of the weights of the elements as determined by spreadsheet analysis (see discussion below). All calculations performed change only the ratios of species to each other, not the overall mass input to the kilns. Over 83% of the total volume in lbs/yr originally calculated is accounted for in these two data bases. The final results of these two data bases are presented in Attachment 2.

To perform the mass balance approach, the next steps are to 1) determine the molecular formulas of the species input to the kiln, and 2) use those formulas in conjunction with the mass balance approach to determine better estimates of the amounts of each species input to the kiln.

First, molecular formulas are entered for each of the materials listed in the data base. The molecular formulas are obtained through CD-ROM data bases; the Registry of Toxic Effects of Chemical Substances Data Base from the National Institute for Occupational Safety and Health (RTECS from NIOSH, updated 1994), the Hazardous Substances Data Bank from the National Library of Medicine (HSDB from NLM, updated 1994), and the Oil and Hazardous Materials/Technical Assistance Data System from the Environmental Protection Agency (OHM/TADS from EPA, 1985). Other sources of molecular formulas are the Alfa Catalog of Research Chemicals (1993-1994 edition), the Aldrich Catalog Handbook of Fine Chemicals (1994-1995 edition), and the Handbook of Environmental Data and Organic Chemicals 2nd ed. (Versheueren, 1983). Assumptions made during this portion of the data analysis are listed in Table II-1.

At this time, analytical values presented in the third WTI dataset (the analysis results) are used to calculate the estimated volume in pounds per year of each of the metals and anions. The analytes and their calculated values are presented in Table II-2.

These values are then used to calculate analytical correction factors for each constituent of the waste feeds containing one or more of the analytes. The correction factors are used to adjust the waste profile to address discrepancies between the analytical data presented on metals and anions and the estimated percentages for specific constituents presented in the waste profiles. These factors are used to recalculate the total lbs/yr of each constituent in order to force the resulting revised

lbs/yr value to yield the analytically determined amount in moles of the analytes. This is necessary in order to reconcile the difference between the amount of each chemical species calculated to be input to the kilns using the prorated percent values and the amounts of chemical species calculated to be input to the kiln by applying the analytical results to the volume of total materials fed to the kiln. This is a significant source of uncertainty. The consequences of not adjusting the input quantities to reflect the analytical results include the overestimation of elemental inputs for many analytes, and would therefore skew the modeling based on those calculations.

Correction factor = (moles/yr analytical value) / (moles/yr determined from % total constituent)

Once the amounts of compounds containing analytes are revised, their mass is totaled and subtracted from the total mass of their respective stream, pumpable or non-pumpable. This resulting mass is then used to create a different correction factor for the remaining constituents, bringing the total mass back to its original total (the mass balance approach).

Certain compounds contain more than one of the analytes for which subtraction correction factors are developed. For example, some compounds contain both chlorine and bromine. In such cases, only one correction factor is applied. For compounds containing both chlorine and another analyte, the factor for chlorine is always used to adjust the values. Errors due to constituents containing multiple analytes are < 2% in the non-pumpable stream and < 1% in the pumpable stream. Table II-3 lists the correction factors for the analytes.

D.   Potential Sources of Error

These revisions (recalculation of input rates to reflect the analytical results, the dropping out of the data base of ash, miscellaneous, trade name compounds, and 2,3-dibromophosphate) are mainly intended to reduce the miscalculation potentially introduced early in data analysis due to the assignment of a point-value to constituents which are identified originally by a range percent, and to reconcile the profile ranges with analysis results. For example, if an individual shipment of waste is labeled "1,2-Dichlorobenzene, 0 - 30%", it will have an actual 1,2-Dichlorobenzene content within that range. However, since the waste received for destruction might contain several compounds (and perhaps even 1,2-Dichlorobenzene under various names), the percentages when added up by upper range percents could total more than 100%. In such cases, each constituent of the waste will have been prorated and assigned a point-value, with the point values adding to 100%. The ranges

of percent content of most waste shipments seem to be consistently on the high side (possibly due to caution on the part of the shippers), especially in the case of chlorinated compounds.

Once the volumes of constituents containing analytes such as chlorine are revised to reflect actual analytical values rather than arbitrary percentages of waste volume, the reported quantities of these constituents in the data base drop. This drop is significant, varying from several percent in the case of Lithium-containing constituents, to nearly two orders of magnitude in the cases of Silver-containing and Thallium-containing constituents.

Other sources of potential error include the omission of ash, batteries, and miscellaneous categories in the elemental analysis. The deletion of waste streams comprising less than 0.5% of waste volumes early in data analysis may also sacrifice some representativeness. In addition, 13 analysis results listings are incomplete and contain "Not Analyzed" entries for some analytes or "Not Detected" entries. "Not Detected" entries do not include the limits of detection or elaborate on testing methods and are entered as values of zero in subsequent calculations.

E. Limitations

Potential sources of uncertainty in the WTI data base are due to the listing of constituents in conjunction with percentage ranges of content rather than analytical values. The lack of standardization in naming wastes further complicates the effort to form a complete picture of the wastes incinerated over a period of one year. The revision of volumes of waste fed to reflect the analytical values available decreases, but does not eliminate, these concerns.

The fact that the data base containes waste input projections for a period of one year means that the analysis represents average values. Daily or hourly deviations from the "average" waste stream could lead to significantly different results upon incineration.

The clarification of data derived from shipping information, as well as the revision of theoretical waste feed values to reflect analytical results, makes the current version of the data a more realistic representation and more useful for modeling efforts. It is hoped that the revisions also make the data base more meaningful and more comprehensible for future uses than the original collection of waste profile sheets and analytical results.

F. Uncertainty

Key assumptions in the development of the data bases are listed in Table II-4. The uncertainty associated with the volumes of constituents determined in the data base in its final form result from the following:

- The reconciliation of Analysis Results with the anticipated constituent composition for compounds containing correction factors between 0 and 0.1

(see Table II-3). Very few compounds are affected; however, compounds containing iodine, non-amenable cyanide, selenium, silver, antimony, thallium, and chromium are affected;

- The prorating of constituent ranges in isolated specific cases where the upper bounds of the constituent ranges for a waste stream totalled between 200% and 1000% before prorating;

- The reconciliation of Analysis Results with the anticipated constituent composition for compounds containing with correction factors between 0.1 and 0.5 (see Table II-3);

- The reduction in the size of the data base due to dropping those waste streams representing >0.5% of the original total waste input;

- The choice of physical state rather than packaging information as criterion for determining pumpability versus non-pumpability;

- The deletion of unidentifiable compounds;

- The deletion of the ash and "abs" categories; and
- The reconciliation of the analysis results with anticipated constituent composition for those compounds containing analytes with correction factors between 0.5 and 1.0 (see Table II-3).

In general, the sources of uncertainty are due to limitations in the way in which data are reported in the original waste profile, and normalization and other data processing to make the data base usable. It is not anticipated that the resulting uncertainty is greater than one order of magnitude for most chemicals. It should be recognized however, that it is not possible to quantify the uncertainty accurately, since it is necessary to project the types of waste feeds likely to be received by the WTI facility over an extended period of time in the future.

TABLE II-1
ASSUMPTIONS MADE DURING DATA BASE REFINEMENT

Description in Original Database	MRI Assumptions
Antimony salt	$SbCl_3$
Arsenic salt	$AsCl_3$
Barium salt	$BaCl_2 \bullet 2H_2O$
Calcium chromate	$CaCrO_4$
Calcium salt	$Ca \bullet (OCl)_2$
Chlorinated Fluorocarbons	$C_2H_2Cl_2F_2$
DCFM	Dichlorofluoromethane
Hc (hydrocarbons)	C_8H_{18} (octane)
Ketones	Methyl Ethyl Ketone
Mixed organics, alcohols and amines	(Ethanol+ethanolamine)/2
PCBs	Pentachlorobiphenyl[a]
TCFM	Trichlorofluoromethane
Acetates	$C_2H_4O_2$ (acetate ion)
Anhydride	Acetic anhydride
A,a-dimethyl benzyl hydroperoxide	$C_{16}H_{16}O_4$
Chrome compounds	Cr_2O_3 (Cr(III)oxide)
Chlorinated Paraffin oils & waxes	$C_{17}H_{17}Cl_{13}$[b]
Creosote	$C_{14}H_{12}O_{0.1}N_{0.2}$[c]

Notes

[a]   Per OHM/TADS

[b]   Per HSDB; C-12 = 60% chlorine, C-23 = 43% Chlorine. Interpolated for general elemental ratio.

[c]   Per HSDB; creosote =

12% phenanthrene

06% aliphatic hydrocarbons (assumed dodecane)

62% polycyclic hydrocarbons (assumed naphthalene)

09% nitrogenated hydrocarbons (assumed acridine)

09% hydroxy-functional polycyclic hydrocarbons (assumed dihydroxynaphthalene)

Table II-2. Analytical Values for Total Waste Streams (Pumpable & Non-Pumpable)

Analyte	Total lb/yr	Atomic Mass Units	Total g moles/yr
Total water	3,496,624	18.0	8.80e+07
Total Cl	1,758,883	35.5	2.25e+07
Total S	75,805	32.2	1.07e+06
Total Fluoride	28,305	19.0	6.76e+05
Total Ca	46,493	40.1	5.26e+05
Total Bromide	75,373	79.9	4.28e+05
Total Na	16,618	23.0	3.28e+05
Total K	8,932	39.1	1.04e+05
Total P	5,447	31.0	7.98e+04
Total Zn	9,071	65.4	6.29e+04
Total Cu	6,951	63.5	4.96e+04
Total Ba	11,318	137	3.74e+04
Total Li	353	6.94	2.31e+04
Total Pb	7,371	207	1.61e+04
Total Cr	1,782	52.0	1.55e+04
Total Se	2,498	79.0	1.43e+04
Total Cd	2,054	112	8.29e+03
Total Tl	2,474	204	5.49e+03
Total Ag	1,105	108	4.65e+03
Total Ni	365	58.7	2.82e+03
Total Sb	510	122	1.90e+03
Total As	302	74.9	1.83e+03
Total Be	6	9.01	3.05e+02
Total Hg	24	201	5.36e+01
Total I	0	127	0.00e+00
Total	5,558,661		1.14e+08

Table II-3. Analytical Correction Factors

Analytes	Correction Factor
Total I	0.000
Total CN non-amen	0.000
Total Be	1.000
Total Hg	0.140
Total Se	0.0013
Total Cd	0.045
Total Ag	0.036
Total Ni	1.000
Total sulfides	1.000
Total As	0.032
Total Li	1.179
Total Sb	0.049
Total CN	1.000
Total Tl	0.02
Total PCBs	1.000
Total TCFM	1.000
Total Cr	0.039
Total Zn	2.303
Total bromoform	1.000
Total DCFM	1.000
Total Na	1.836
Total P	0.467
Total Cu	7.199
Total Pb	0.123
Total K	9.244
Total Ba	0.305
Total fluoride	1.000
Total S	0.231
Total Ca	2.947
Total Bromide	0.015
Total Cl	0.463
Total water	1.000

Table II-4 Key Assumptions for Chapter II			
Assumption	**Basis**	**Magnitude of Effect**	**Direction of Effect**
In applying the waste profile data, individual waste streams that comprise less than 0.5% of the total volume are deleted	The small quantity of these waste streams limit their effect, so this simplifying assumption focuses the assessment on the waste streams that present the most significant health hazard	low	underestimate
In estimating the constituent content in a waste stream, the upper bound of the reported range for each waste stream constituent is used. To prevent the combined percentage from exceeding 100%, the constituent content of the waste streams are normalized.	Conservative estimate. Professional judgment based on facility desing and operation, and predicted waste characterization.	low	overestimate
The waste feed data is based on waste profile sheets for the first nine months of operation.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics and receiving patterns.	medium	unknown

CHAPTER III. ESTIMATION OF UNMEASURED METALS EMISSIONS AND EVALUATION OF METALS BEHAVIOR AT THE WTI INCINERATOR

A. Concerns to be Addressed

The portion of the March 1993 trial burn that focused on the emissions of metals was designed and conducted using an appropriate protocol, but the emissions of several metals of interest in the risk assessment were not measured. Thus, an appropriate method for estimating the emissions was needed.

B. Approach

Different methods for estimating the emissions of the unmeasured metals are evaluated and an appropriate modeling procedure is selected. The modeling approach chosen addresses the issues raised in the peer review comments. It predicts the reactions and phase transformations of metals in the incinerator using thermodynamic equilibrium calculations. Condensation processes are modeled. The particle dynamics program MAEROS is used to predict the evolution of the particle size distribution. Particle size specific estimates of the removal efficiencies of the system are determined using the March 1993 trial burn data. The modeling approach is used to conservatively estimate the emissions of the unmeasured metals.

The model is used to examine the impact of several operating parameters on the predicted emissions. The model is capable of predicting metals speciation and the distribution of the metals across the range of particle sizes.

C. Estimation Technique Selection

The goal of this effort is to provide reasonable estimates of the emissions of the metals for which there are no trial burn data for use in the risk assessment. Emissions data are not reported for three classes of metals. The first class consists of the regulated metals for which the facility elected to comply with Adjusted Tier I feed rate limits. These metals are silver (Ag), barium (Ba), and thallium (Tl). The second class consists of toxic metals identified in the regulations for Boilers and Industrial Furnaces burning hazardous wastes (BIFs) but not included in current guidance or regulations for dedicated hazardous waste incinerators. These metals are nickel (Ni) and selenium (Se). The third class contains unregulated metals that may be important in multi-pathway risk assessments. These metals are aluminum (Al), copper (Cu), and zinc (Zn). It is useful to also consider the metals that

are measured in the trial burn — antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg). These metals provide information on the validity of the estimation procedures since the actual emissions rates are known.

Three potential estimation techniques were evaluated in this preliminary analysis:
- Review of raw analytical data;
- Review of historical data; and
- Modeling.

Each of these techniques is discussed below.

1.   **Review of Raw Analytical Data From Trial Burn**
The trial burn report provided information on the seven target metals for which Tier III permit limits were needed. Analytical laboratories, however, often generate at least semiquantitative data on non-target metals, when inductively coupled argon plasma (ICAP) emission spectroscopy is used for analysis. Instrumentation used for ICAP analysis is generally capable of simultaneously measuring over 30 metals or other inorganic elements, but the accuracy of those measurements depends on how specific standards and other quality control (QC) steps are used.

It was thought possible that the ICAP raw data from the trial burn included information on at least some of the other eight metals of interest. A detailed list of raw data and laboratory procedural items was obtained to determine if this was a method to estimate metals emissions. Although the data may have been only semiquantitative, they might still have been superior to values obtained from other emission estimation methods. The major limitations of this search were:

- The waste feeds apparently were not analyzed for metals; and
- "Synthetic" wastes were developed from "pure" materials and used for the trial burn (along with spiking of metal compounds and other toxic constituents), so that many of the eight untested metals of interest may not have been present in the trial burn feeds.

In spite of the above limitations, a quick review of the stack emissions raw ICAP data for any of the eight metals of interest seemed appropriate because:

- Waste feed samples were obtained by the Ohio EPA and may have been available for analysis;

- Depending on the purity of the spiking compounds used, there may have been sufficient levels of some of the metals of interest present as impurities to allow some evaluation of control performance; and
- Some of the feed components may have contained some of these metals (e.g., the cellulose-based batch solid waste may have contained Cu or Zn).

If any of the metals of interest were found in the stack samples, then trial burn feed rate information for those metals could have been obtained or estimated, as possible. For instance, there may have been published data on typical levels of trace metals in certain feed materials.

However, appropriate data were not found to be available. Thus, it was not possible to use this technique to obtain the necessary estimates.

2. Review of Historical Data

A brief search for relevant historical data on relative metals control performance was performed. The main objective was to obtain, for a hazardous waste incinerator (or possibly other combustion device), metals control data (e.g., input rates, emission rates, system removal efficiencies, and/or collection efficiencies across specific air pollution control devices). Data were needed for any of the eight metals of interest, as well as many of the remaining seven metals which were reported for the WTI trial burn. Ideally, the data should have been from an incinerator equipped with similar air pollution control equipment (APCE) to the WTI incinerator.

Several potential sources of control performance data were identified, where the metals measured included at least some metals which were measured during the March 1993 WTI trial burn and some which were not measured. Unfortunately, none of these tests were performed on an electrostatic precipitator (ESP)-equipped hazardous waste incinerator. Furthermore, no hazardous waste incinerators were identified with an APCE train similar to that at WTI (i.e., boiler, spray dryer, activated carbon injection system, ESP, quench, packed bed scrubber). In fact, no incinerators with even a general sequence of a spray dryer followed by an ESP were identified, with one possible exception. Von Roll's Biebesheim facility in Germany was believed to have been outfitted to this general system, however, waste feed data were not available. Thus, it was concluded that sufficient historical data to estimate emissions were not available.

3. Modeling of Metals Emissions

Modeling can be used as a "tool" to combine relevant empirical data with general knowledge of the chemistry and physics involved to predict how the metals of interest behave. Several modeling approaches have been used to examine the behavior of metals in waste incineration systems. These range from the comprehensive computational model of the behavior of metals in waste combustion systems that was developed by Barton et al. (1990) for the EPA's Risk Reduction Engineering Laboratory to semi-empirical approaches such as that developed by Biswas et al. (Biswas et. al 1992). The majority of the models assume that chemical equilibrium is maintained for the metals within the waste. The two main weaknesses of this approach are—detailed thermodynamic data on all species and complexes that may possibly form are required and may not be available; and, the model does not account for condensed phase non-idealities. However, the only successful general modeling approaches available are based on the equilibrium approach.

4. Conclusion

Based on the review of different estimation techniques, the application of a modeling procedure provides the best estimates of metals' behaviors. An approach similar to that developed for the EPA based on the assumption that chemical equilibrium is maintained throughout the incinerator system is deemed to be the most appropriate.

D. Emissions Estimation

1. Introduction

This section consists of seven subsections as follows:

- *Model Development*

  This subsection summarizes the current understanding of the processes controlling metals' behavior as they apply to the WTI incinerator. The conceptual model and computational techniques used to estimate emissions from the WTI incinerator are described. Assumptions and simplifications used are discussed.

- *Model Application*

  This subsection describes the data used and the resulting emissions estimates. The sensitivity of the emissions estimates to variations in selected parameters are investigated.

- *Uncertainty Analysis*

  This subsection describes and quantifies the uncertainty associated with the predicted emissions.

- *Speciation*

  This subsection discusses issues related to prediction of the metal species emitted.

- *Other Topics*

  This subsection addresses the three additional limited topics related to the assessment of the risk associated with the emission of metals from the WTI facility.

  - Evaluate the health risks associated with aluminum emissions.
  - Model the ratio of Cr(III) to Cr(VI) in the incinerator stack and at the receptor.
  - Evaluate the potential for trace impurities in the scrubber water to become stack emissions.

- *Conclusions*

  This section summarizes the predicted emissions estimates and the limitations of the estimates. Recommendations for improving the estimates are listed.

2. **Model Development**

   a. **Background - Trial Burn Data**

   Examination of the March 1993 trial burn data included in the trial burn report (WTI, 1993) provides insight into the behavior of the unmeasured metals. Emissions data for metals were only reported for the test conditions intended to maximize the emission of metals (that is, Runs 1, 2, and 3). Combustion chamber temperature was maximized at this condition. The average temperatures for each test ranged from 2160° to 2200°F (1180° – 1200°C). This temperature was measured at the inlet to the secondary combustion chamber (SCC) and thus is not the actual primary chamber temperature. However, the measured temperature should be closely related to the actual primary chamber temperature.

The system removal efficiencies (SREs) measured during the trial burn are summarized in Table III-1. SRE is defined as:

$$SRE = 1 - \frac{Emission}{Feed} \qquad (1)$$

"Emission" is the emission rate of a given metal on a mass basis and "feed" is the feed rate of the metal on a mass basis.

Three sets of metals are defined based on the SRE data.

1. Mercury (Hg). The SREs for mercury are very low (4.40 to 10.59 %). Mercury is known to be a vapor even after the flue gases have been cooled to ambient conditions. The control system in place at the WTI incinerator when the trial burn was conducted was not effective at removing mercury vapors.

2. Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), and Lead (Pb). The SREs for these metals are similar (99.97% to 99.995%). This implies that similar mechanisms controlled the behavior of these metals.

3. Chromium (Cr). The SREs for chromium are very high (99.99996%).

More information is obtained by looking at the SREs for metals in Group 2 in greater detail. Figure III-1 is a graph of the system penetration of each of these metals (system penetration=1-SRE). The metals are ranked in order of increasing penetration. The ranking agrees with the volatility ranking systems developed by the EPA and investigated at the Incineration Research Facility (Waterland and Fournier 1993). This indicates that the observed SREs are influenced by the volatility of the metals.

b. Current Theory

To understand the modeling approach used, it is useful to understand the mechanisms thought to control the behavior of metals in waste combustion systems. Several researchers have been investigating this behavior. Data generated by these programs were reviewed by Barton et. al., (1993) Seeker (1990) and Linak and Wendt (1993). These reviews synthesized a mechanistic understanding of the phenomena that control the behavior of metals in waste

combustion systems. The complexity of the proposed mechanisms has increased over time. A simplified discussion of the current mechanistic understanding as it applies to the WTI incinerator follows. The sources cited above contain a more complete discussion of the general mechanism.

Figure III-2 illustrates the pathways metals may take through the WTI incinerator. Many interrelated mechanisms control the pathway a given metal will take. These mechanisms are dependent on the physical form and chemical composition of the original waste, the chemical speciation of the metal within that waste, and the way in which the metals are dispersed within waste. The strong influence of physical state implies that the pumpable and non-pumpable wastes should be considered separately.

Most of the inorganic material present in the non-pumpable waste is expected to form slag (Eddings and Lighty 1992). The slag flows through the kiln and into an ash quench pit where it is quickly cooled to near ambient temperature. A small fraction of the slag may be entrained by the flue gases. Non-volatile metals present in the non-pumpable waste will remain in the slag. Most volatile metals present will vaporize. However, some of the volatile metals may react with the slag to form refractory complexes which remain with the slag (Eddings and Lighty 1992).

Pumpable waste is injected through a sludge lance, a slurry burner or a liquid burner. These devices break the pumpable waste stream into a cloud of small drops. A large fraction of the ash formed by these drops will be entrained by the flue gases. The size of the particles formed will be a function of the size of the drops and the physical distribution of the ash within the waste. The non-volatile metals and the metals that interact strongly with the ash remain with the entrained particles. Most volatile metals present in the pumpable waste will vaporize.

Non-volatile metals from either the pumpable wastes or non-pumpable wastes may interact with components of the waste or the flue gas to form volatile compounds. Two types of reactions have been observed. In the first type, reactive elements released during the incineration process interact with metals (Quann and Sarofinn 1982). The resulting species may be much more volatile than the original species causing the metal to vaporize. The second class of reactions occurs in the high temperature, reducing environment formed near the burning waste. This environment forms in nearly all waste combustion systems even if the incinerator is operated at overall excess oxygen conditions (Quann and Sarofinn 1982). The reactions principally involve the reduction of

metal oxides. The newly formed species may have a different volatility than the original species.

After the primary chamber, flue gases contain metals on entrained particles and in the vapor state. Additional reactions may occur in the flue gases as a result of variations in temperature and gas composition. These reactions may result in the formation of compounds with different volatilities than the original compounds and subsequent vaporization or condensation of material. In addition, reactions may be promoted by the addition of reactive solids to the flue gases (Uberoi et al. 1990) such as activated carbon.

As the flue gas cools, metals will condense both homogeneously to form new particles and heterogeneously on the surfaces of the entrained ash particles (Senior and Flagen 1982). Homogeneous condensation (nucleation) produces particles that are much less than 1 μm in diameter (Friedlander 1977). Heterogeneous condensation tends to favor small particles due to their high surface area to volume ratio (Linak and Peterson 1984). Thus, the small particles have higher concentrations of the volatile metals than the original waste. The concentrations of metals such as silver, cadmium, lead and antimony in particles emitted from waste combustion facilities have been found to be 30 to 100 times higher than would be expected if no vaporization and condensation occurred.

The particles formed collide with one another and with the entrained ash. When the particles stick together, these collisions result in coagulation of smaller particles into larger particles. Small particles are extremely mobile, are present in large numbers and coagulate quickly. As the particles become larger, their mobility and number concentrations decrease resulting in a lower coagulation rate. Investigations of combustion systems have found that any particles smaller than about 0.1 μm quickly coagulate, while those larger than 1 μm do not (Linak and Wendt 1993). Thus, the small particles formed by homogeneous condensation quickly coagulate to form 0.1 μm particles at which time the coagulation rate slows dramatically. Larger particles do not coagulate significantly in the incinerator. Due to these mechanisms, two groups of particles typically enter the air cleaning system. One group ranges in size from 0.1 to 1 μm and is formed from the metals that vaporized and subsequently condensed. The second group is larger than 10 μm in diameter and consists of the material entrained in the incinerator (Linak and Wendt 1993).

The specific mechanisms responsible for removal of metals from flue gases vary from device to device. The principal mechanisms responsible for

removal of metals in any given device are generally well known and are described in the many texts in the area (e.g., Wark and Warner 1981). Three features of these mechanisms are important to the development of an appropriate model. First, particle collection efficiency is a function of particle size. Second, most flue gas cleaning devices are least efficient at capturing solid particles that range in size from about 0.1 μm to 1 μm (Wark and Warner 1981). Third, vapor collection is a function of the solubility of the vapor in the fluid used.

c.   **Modeling Approach for WTI Incinerator**

A Legrangian approach (the control volume moves with the flow of material through the reactor) is used as the basis for the model of the behavior of metals at the WTI facility. Figure III-3 illustrates the modeling approach. Two feed streams enter the primary combustor — pumpable wastes and non-pumpable wastes. Data on the bulk composition, concentration of metals and feed rate of each waste stream are provided to the model. In addition, the conditions (temperature and oxygen concentration) are provided. The primary chamber model uses these data to predict any reactions that may occur and the subsequent vaporization of any metals. The primary chamber model also predicts the quantity of material that is entrained. The specific techniques used are described below. The data produced by the primary chamber model include:

- Quantity of each metal in the residuals (slag);
- Quantity of air required;
- Quantity of each metal which is in the flue gases as vapors;
- Entrained particles; and
- Flue gas flow rate and composition.

The flue gas then flows into the secondary combustion chamber (SCC) carrying any entrained particles and vapors with it. The model is capable of predicting any physical or chemical changes that may occur in the SCC. However, the conditions in the SCC at the WTI facility are similar to those in the primary chamber so no changes are expected to occur. Thus, no calculations are performed for the SCC.

The processes which occur in the flue gas cleaning system are simulated by two models. The chemical and physical transformations that occur are simulated by the quench model. The removal of particles and gases from the

flue gases is simulated by the flue gas cleaning model. These calculations are performed sequentially though the processes are simultaneous. Creation of a model that would account for both of these processes simultaneously is beyond the scope of this effort. Previous work by Barton et al. (1990) indicates that performing the calculations sequentially probably has little impact on the final predictions and significantly reduces the computational effort and data required.

The flue gas composition predicted by the primary chamber model is combined with data on the conditions in the quench by the quench model. This model predicts any reactions and condensation that occur when the flue gases are cooled. The model predicts the quantities of metals present as vapors, fine particles (< 1 µm) and coarse particles (>1 µm). The specific procedures used are discussed below.

The final calculation uses data on the efficiency of the flue gas cleaning system at removing each class of material from the flue gases to determine the emissions. Ideally, in the absence of measured emissions for metals not tested during the trial burn, models based on theoretical considerations would be used to predict the control efficiencies. However, no suitable models are available for the devices present at the WTI incinerator. Thus, for metals not tested in the WTI trial burns, efficiencies derived from the trial burn data for metals which are tested are used as discussed below.

d. Waste Composition

The composition of each waste feed, including the concentration of the metals of interest, is one of the most important parameters in predicting the emission rates. The chemical composition profiles described in Chapter II are used. Data are available for all of the metals of interest except Al.

Although a wide variety of waste feed scenarios can be envisioned, a simplified approach is used for this task. A time-averaged (that is, annualized) waste composition for each of the two feed streams is used. These values are based on the potential annual production rates of each component of the facility's total waste stream. The composition of the pumpable and non-pumpable waste streams are summarized in Table III-2. The total waste feed rates and individual metal feed rates determined are compared to existing RCRA permit limits. This comparison is summarized in Table III-3. The approach assumes that each waste type will be fed at the maximum rates envisioned and appears to be reasonably conservative. However, it ignores

short-term variations in the feed rate of any given metal. Details on the development of the waste composition are provided in Chapter II.

The annualized average feed rate described above is below the maximum allowable heat input for the system. Thus, a second case is examined in which the wastes would be fed at the maximum heat input rate allowed based on the design of the kiln (121 MBTU/hr on a higher heating value basis). This maximum feed rate is 4.10 times greater than the annualized average feed rate. The composition of each waste stream is not altered for this case.

e.   Incinerator Operating Conditions

The values for key operating conditions in the primary chamber are:

*   Temperature = 1200°C; and

*   Air to waste stoichiometric ratio = 1.0 (no excess oxygen available).

Research indicates that the greatest potential for the vaporization of metals occurs at the flame front (Barton et al. 1990). At this location the temperature is maximized and there is no excess oxygen available (the feed to air stoichiometric ratio is 1). The temperature measured at the entrance to the SCC is assumed to be the maximum temperature.

f.   Chemical and Physical Transformations

The chemical and physical transformations that each metal undergoes in the incinerator and in the quench are determined assuming that equilibrium is continuously maintained. Two computer programs capable of determining the equilibrium composition of a mixture are used. The programs are CETPC (an equilibrium calculation computer program developed by NASA (Gordon and McBride 1994)) and HSC Chemistry for Windows Version 2.0 (a commercial equilibrium calculation program marketed by ARSoftware Corp.). The programs are used to determine the vapor pressure of each metal in the incinerator and in the quench. These thermodynamic codes function by minimizing the Gibbs free energy of a system given the elemental composition, temperature, pressure, enthalpy and possible resultant species. A major limitation is that erroneous results may occur if all important resultant species are not included (either by choice or due to lack of sufficient thermodynamic data).

It should be noted that chemical equilibrium will probably not be achieved in all sections of the incinerator due to kinetic limitations. Studies

conducted at the University of Utah and the EPA, among others, indicate that behavior not predicted by equilibrium models may occur in some systems (Linak and Wendt 1993; Eddings and Lighty 1992) due to the formation of solid solutions or refractory complexes. Thermodynamic data for these systems are not generally available. However, equilibrium-based models are effective for most systems and are the best approaches available.

Two kinetic limitations are incorporated into the reaction modeling. The compounds $PbCl_4$, and CrO_2Cl_2 are commonly predicted to form at low temperatures by the thermodynamic programs. These predictions are probably not correct because of kinetic limitations (Linak and Wendt 1993 and Ihara et al. 1983). However, due to the lack of a validated test method for measuring these two species, test data confirming this is not yet available. Inclusion of these compounds can make lead and chromium appear to be much more volatile than they are generally observed to be. Thus, these two compounds are excluded from consideration during the thermodynamic modeling.

g.   Entrainment

No acceptable entrainment models are identified. Li (1974) and Tackie et al. (1990) have examined entrainment in kilns containing granular material. Their models are semi-empirical and can not be directly adapted to a slagging kiln. Thus, an engineering assessment of the entrainment potential is required. It is assumed that no entrainment of the slag occurred. All of the pumpable waste is injected through a sludge lance, a slurry burner or a liquid burner. These devices break the wastes into small drops that form solid particles as the volatile material is driven off. Most of these particles are entrained. It is assumed that all of the pumpable ash is entrained.

h.   Particle Dynamics

Two assumptions simplify the particle dynamics considerations.

•   All material that vaporizes and subsequently condenses, forms particles with diameters of about 0.5 μm; and

•   No material condenses onto the surface of the entrained particles.

These assumptions are based on an examination of coagulation and condensation processes as described below.

Coagulation. Coagulation processes have been studied extensively over the past decade and many of the basic mechanisms are relatively well understood. Several models have been developed and some of the more recent approaches are summarized by Seigneur et al. (1986). The MAEROS model was developed by Gelbard (1980) and is widely accepted. It accurately tracks the evolution of many types of aerosol over time. Its main limitations are that it does not account for condensation processes and sometimes fails to arrive at acceptable solutions for very short time periods (on the order of 0.1 s).

MAEROS is used to examine the evolution of an aerosol that is similar to that which would form in the WTI incinerator. It is assumed for the evaluation that only very small particles (0.01 to 0.05 μm in diameter) are present initially. These represent the nuclei formed by the initial wave of homogeneous condensation. Figure III-4 illustrates the evolution of the aerosol in a gas at 1400 K. In 0.5 s, nearly all the nuclei have formed particles 0.1 to 0.5 μm in diameter. After 120 s, the aerosol has stabilized with all of the mass that started as nuclei having shifted to 0.5 to 1 μm. Figure III-5 illustrates the aerosol evolution predicted if the gases are at 400 K (approximately the quench temperature). The growth of the nuclei is retarded. After 120 s, only about half of the mass has grown to the 0.5 to 1 μm range. These two cases define the coagulation rate extremes that may be observed.

These findings are substantiated by other models and by experiments (Linak and Wendt 1973). In typical gas residence times in an incinerator, bimodal particle distributions are usually generated. One mode occurs around 0.5 μm and is the result primarily of vaporization, condensation and coagulation processes. A second mode occurs above 1 μm and is the result of entrainment.

Condensation. The relative importance of homogeneous condensation, condensation onto fume nuclei, and condensation onto entrained particles can be assessed using classical condensation theory. Nucleation rates can be estimated using the Becker-Düring equation (Friedlander 1977). Heterogeneous condensation can be estimated using diffusion and gas kinetics considerations as described by McNallan et al. (1981). At conditions typical of the incinerator, the relative rate of each type of condensation is shown in Figure III-6. Heterogeneous condensation on the surfaces on fume particles is the predominant form of condensation. When fume particles are present, almost no material condenses by either of the other two modes.

i. Flue Gas Cleaning

The flue gas entering the cleaning system contains vapors, fine particles (0.1 to 1 μm) and coarse particles (>10 μm). The efficiency of the control system at removing each class of material is assumed to be different. However, due to the complexity of the pollution removal system and the limited resources available, it is not possible to calculate the efficiency of the system for each class of material based on fundamental principles. Data from the trial burn are used to determine the needed efficiencies.

Two classes of vapors can be identified. Soluble vapors dissolve easily in the scrubbing solutions used in the flue gas cleaning system while insoluble vapors do not. The observed control efficiency for mercury in the trial burn is assumed to be the flue gas cleaning system efficiency for removal of all insoluble metal vapors. Mercury is generally present in flue gases in a form that is probably insoluble (Vogg et al. 1986). In addition, it is known to be present as a vapor. No metal that is both soluble and known to be present as a vapor was used in the trial burn. Thus, another monitored material that is present in flue gas as a soluble vapor must be identified to establish the ability of the flue gas cleaning system to remove this class of materials. Two likely compounds are identified - HCl and SO_x. Of the two, SO_x generally exhibits lower solubilities and lower removal efficiencies than HCl. Thus, the removal efficiency of SO_x is selected as a conservative estimate of the ability of the flue gas cleaning system to capture soluble vapors. The relative solubility of each metal is determined based on the compound predicted to form by the thermodynamic calculations and summaries of compound solubility (Weast 1974). Table III-4 summarizes the soluble and insoluble metals.

The control efficiency for arsenic observed in the trial burn is assumed to be the control efficiency for all fine particles (that is particles with diameters of 0.1 to 1 μm). The assumption is justified by the following observations:

- Arsenic is volatile and it is likely that all of the arsenic present in the waste during the trial burn vaporized; and
- Thermodynamic calculations indicate that arsenic will condense in the flue gas cleaning system. As discussed above, all material which condenses will probably be present as fine particles.

Based on these observations, it is probable that all of the arsenic originally present in the waste entered the flue gas cleaning system as fine

particles. Thus, the control efficiency of arsenic should be the same as the fine particle removal efficiency.

The trial burn data from chromium is used to determine the flue gas cleaning systems removal efficiency for coarse particles. Chromium is expected to be the most refractory metal examined in the trial burn. Thus, the only mechanism which will result in chromium being present in the flue gas cleaning system is entrainment. As discussed previously, entrainment results in the presence of coarse (>10 mm) particles. However, chromium is divided between the pumpable waste and the non-pumpable waste. To be consistent with the assumptions that the ash from non-pumpable waste is not entrained and that all of the ash in the pumpable waste is entrained, it is assumed that only the chromium from the pumpable waste would be present in the flue gas as entrained particles at the entrance to the flue gas cleaning system. Thus, the coarse particle control efficiency would be:

$$1 - \frac{Cr_E}{Cr_F^P} \tag{2}$$

Cr_E is the mass emission rate of chromium in the trial burn and Cr_F^P is the feed rate of chromium in the pumpable waste stream. Table III-5 summarizes the control efficiencies used for each class of material.

3. Model Application

a. Preliminary Validation

To determine if the modeling procedure produces reasonable predictions, it is first used to predict the behavior of metals under the conditions used in the trial burn. The waste feed composition is summarized in Table III-2. The results of the comparison are summarized in Figure III-7. The predictions for arsenic, mercury and chromium are very close to the actual values. However, this result is to be expected because the control efficiencies are based on these metals. The predictions for all of the other metals observed during the trial burn also agree well with the observed values. The greatest difference is observed for beryllium where the prediction is about twice the observed value. In all cases, the predicted emissions are higher than the observed emissions indicating that the predictions are likely to be conservative.

It must be noted that this comparison is not a rigorous validation of the prediction procedure but is rather a preliminary gross check on the realism of the predictions. A more extensive validation of the procedure is needed to increase the confidence in the results. However, a similar predictive approach has been compared with data from boilers and industrial furnaces (BIFs) and has been found to agree with measured values to within an order of magnitude over a broad range of conditions (Clark et al. 1994).

b.   Predictions

The procedures are used to predict emissions from the incinerator under the assumptions described above. Table III-6 summarizes the results. Emissions predicted for the annualized average waste feed rate and the maximum heat input feed rate cases are included in Table III-6. For the metals that were measured during the trial burn, it is possible to calculate predicted emissions using the SREs determined in the trial burn. The emissions predicted using that technique are also summarized in Table III-6. It should be noted that extrapolation of trial burn data in that manner is not generally conservative. However, the modeling results indicate that for the metals measured in the trial burn, the specific incinerator conditions expected and the specific quench conditions used, the SRE values do not change with the metals' feed rate. Thus, for this limited case, the model indicates that extrapolation of the trial burn SRE data is conservative.

c.   Sensitivity Analysis

The sensitivity of the predictions to variations in assumed values is examined. For each parameter examined, alternative values are selected and used as input for the model. The results produced are compared with the base case presented above. The following parameters are investigated:

- Feed rate;
- Combustion chamber temperature;
- Combustion chamber stoichiometry;
- Waste chlorine concentration;
- Quench temperature; and
- Entrainment rates.

The behavior of each of the 15 metals listed in Table III-6 is examined.

1. Feed Rate

The impact of feed rate on the predicted behavior of each of the 15 metals is evaluated. Three feed rates for each of the 15 metals are examined as follows:

- Base case (the maximized heat input feed rates);
- High feed rate (one order of magnitude greater than the base case); and
- Low feed rate (one order of magnitude lower than the base case).

Emission rates change proportionately for each metal and the predicted SREs are constant. This result does not imply that, in general, SRE is not affected by feed rate. It only implies that the feed rates examined are much higher or much lower than needed to saturate the flue gases with any of the metals. If the feed rates are close to those needed to saturate the gases, small changes in feed rate may have a significant impact on the predicted SREs.

2. Combustion Chamber Temperature

Four combustion chamber temperatures are examined — 1000°C, 1100°C, 1200°C and 1400°C (1830°F, 2010°F, 2200°F and 2550°F). The temperature of 1200°C is used in the base case predictions reported above. Figure III-8 summarizes the emission rates and system penetration predicted for each chamber temperature. The emissions of Be, Cu and Ni are affected by the change in temperature. At the two lower temperatures, no beryllium vaporized in the combustion chamber. The emissions decreases from 1×10^{-7} g/s in the base case to less than 1×10^{-8} g/s at the two lower temperatures.

Vaporization of copper and nickel is reduced at 1000°C. The emissions of both of these metals is approximately one order of magnitude lower at 1000°C than at any of the other temperatures. At the higher temperatures, Be, Ni and Cu are predicted to vaporize and condense forming fine particles. At the lower temperatures, the metals will remain with the ash. Thus, the changes in the SREs reflect the transfer of these metals from the fine particles to the coarse particles.

3. Combustion Chamber Stoichiometry

Two primary chamber stoichiometric ratios are examined in addition to the base case in which the ratio is 1.0. The additional ratios are 0.8 and 1.2. Figure III-9 summarizes the results of the calculations. Both emission rates and system penetration are shown. Be and Ni are the only metals effected by the change in the quantity of air present. At low oxygen concentrations, the vaporization of Be is lower than in the base case due to the formation of reduced forms that are less volatile than the oxide. The predicted Be emissions are approximately one order of magnitude lower when the stoichiometric ratio is 0.8 than when it is 1.0. The predicted nickel emissions are about one order of magnitude lower when a stoichiometric ratio of 1.2 is used. The SRE for nickel increases from 99.977% to 99.997% at the higher oxygen concentration.

4. Waste Chlorine Content

The impact of chlorine is examined. Emissions are predicted for a waste that did not contain chlorine and the results are compared with the maximum heat input case. The comparison is illustrated in Figure III-10. Cu, Ni, and Se are effected by the removal of all chlorine from the system. In the absence of chlorine, copper and nickel no longer vaporize in the primary combustion chamber. As in the previous two analyses, when the vaporization in the primary chamber is eliminated, the emissions drop by about one order of magnitude and the SREs increase dramatically.

Selenium, in contrast, still vaporizes in the primary chamber when no chlorine is present. However, the vapors condense in the quench if there is no chlorine present. This results in a decrease in emissions by about an order of magnitude and an increase in the predicted SRE from 99.7% to 99.98%.

These results do not imply that the other metals do not form chlorides that are more volatile than the oxides. Some, such as lead and cadmium, do form volatile chlorides (Barton et al. 1990). However, the temperature in the primary chamber is high enough to vaporize the oxides of these metals and the quench chamber is cool enough to condense the chlorides. Thus, the predictions are unaffected by the formation of the chlorides.

5. Quench Temperature

Two quench temperatures are examined in addition to the base value of 150°C. The additional values are 200°C and 400°C. Figure III-11 summarizes the comparison. Emission rates and system penetrations are shown. Cd, Sb, Tl and Zn are affected by the quench temperature. As the temperature increases, condensation of these metals decreases. Emissions increase correspondingly due to the low capture efficiency for vapors. Tl emissions are one order of magnitude higher than the base case for both of the higher quench temperatures. Zn and Cd emissions are one order of magnitude higher than the base case at 400°C only. Sb emissions are slightly higher than the base case at the highest quench temperature. When the emissions rates increase, the predicted SREs decrease.

6. Entrainment

The final parameters examined are the entrainment rates assumed for the slag and the pumpable waste. In addition to a pumpable waste entrainment rate of 1.0 and a non-pumpable waste entrainment rate of 0.0, a pumpable waste entrainment rate of 0.5 and a non-pumpable entrainment rate of 0.2 are examined. Figure III-12 summarizes the results. Cr and Al, the two least volatile metals, are affected by the changes. Decreasing entrainment of pumpable material decreased emissions and increased SRE. Increasing the entrainment of non-pumpable wastes increased emissions and decreased SRE slightly.

E. Uncertainty Analysis

This section briefly discusses the uncertainty in the predicted emission rates of those metals for which no trial burn data are reported.

1. Modeling Assumptions

The model used to make the predictions reflects the current state of the art for estimating metals behavior in waste incineration systems. However, several assumptions are inherent in the model which fundamentally limits its capability to precisely predict the emissions of metals. Some of the most important of the limiting assumptions are:

a. **Thermodynamic equilibrium is maintained throughout the incineration and flue gas cleaning system.** This assumption is required because in most cases the needed reaction rates are not known. Because sufficient kinetic data are not available, it was not possible to precisely quantify the impact of assuming equilibrium is maintained. However, for most metals it is unlikely that the assumption had any impact on the predicted emissions. The quantity that vaporizes at incineration conditions is often independent of the chemical form of the metal. Similarly the quantity which condenses in the quench is also often independent of the chemical form. However, care must be taken in applying this assumption for there are a few specific metals and condition where the chemical form can have a significant impact.

b. **All important compounds are present in the thermodynamic database.** Recent experiments show that complex reactions between ash components and certain metals are possible. The complexes which form have different volatilities than the other forms of the metal and are not generally present in the thermodynamic data base. It is not believed that this has a major impact on the predicted emissions in this case.

c. **The reactor outlet temperature adequately characterizes the temperature to which the metals are exposed.** In fact, the temperatures in the incinerator vary significantly. The behavior of the metals, as demonstrated by the sensitivity analysis can vary significantly with temperature. Comparison of the emissions measured in the trial burn with the model's predictions indicates that representative conditions have been selected and that the model did not under predict emissions.

These assumptions are necessary and are the best that could be made given the base of information available. However, they limit the fundamental precision of the model and render a rigorous error analysis premature.

2. **Data**

It is possible to evaluate the impact of variations in the data used by the model on the predicted emissions. The data fall into two classes:

- Site-specific data; and
- General data.

Site-specific data include such items as combustion chamber temperature and waste feed composition. General data includes thermodynamic data, gas viscosities, and similar parameters. The general data are more precisely known than the site-specific data and contribute little to the potential error in the predictions. Because of this, the impact of site-specific data only are examined. The following parameters are used in the model:

- Waste Composition and Feed Rate
  - Chlorine
  - Trace metals

- Conditions in Incinerator System
  - Temperature
  - Availability of oxygen
  - Entrainment
  - Quench temperature

- Control Device Efficiency
  - Vapors
  - Fine Particles
  - Coarse Particles

The effect of reasonable variations in several of these parameters are examined. These are waste feed rate, combustion chamber temperature, availability of oxygen, waste chlorine concentration, quench temperature and entrainment rates. With the exception of waste feed rate, each of these parameters will affect the behavior of only a few of the metals. However, the impact on the metals affected can be significant (changes in emission rates of more than an order of magnitude).

3.   Removal Efficiencies

Control device removal efficiencies for vapors, fine particles and coarse particles are determined based on the results of the March 1993 trial burn as is described above. The control efficiency for insoluble metals was estimated based

on the March 1993 trial burn collection efficiency of mercury. The control device efficiency for collecting soluble metals was estimated based on the trial burn values for SO_x. The efficiencies for fine and coarse particles are estimated based on the trial burn values for arsenic and chromium. The uncertainty in the predicted removal efficiencies is estimated by calculating the standard deviation observed during the three test runs conducted during the trial burn. Table III-7 summarizes the control efficiencies used and the associated standard deviations. Because the control efficiencies are estimated using data obtained during the trial burn in a series of tests repeated over a short time using a well controlled simulated waste, it is likely that the values in Table III-7 represent the smallest possible variability. In operation over long times, it is likely that the variation in waste composition, emission values and perhaps control efficiencies would be much greater.

4. Uncertainty Estimates

Based on the values in Table III-7 and the sensitivity study discussed above, it was possible to determine the range of variation that may be expected in the predicted emissions rates. Table III-8 summarizes this analysis. The minimum value is obtained by using the model to predict emissions when all the data are at the values which produced the lowest predicted emissions. Thus, this prediction used the lowest reasonable entrainment rates, primary chamber temperature, quench temperature, chlorine concentration, and metals feed rates. The impact of oxygen concentration is relatively small and is not included in this analysis. In addition, the control efficiency is assumed to be one standard deviation greater than the average from the March 1993 trial burn. The maximum value is obtained using a similar technique. The highest reasonable entrainment rates, primary chamber temperature, quench temperature, chorine concentration, and metals feed rates are used simultaneously. The control efficiencies are assumed to be one standard deviation less than the March 1993 trial burn averages.

The feed rate of each metal has a strong impact on the predicted emission rate. Variation in the feed rate accounts for most of the variation observed in the predicted emission rates for each metal. For this analysis, it is assumed that actual feed rates could deviate from the maximum heat input feed rate by as much as an order of magnitude. This wide range of possible variation in metals feed rates is based on the following observations:

a.	The concentration information in the data base used to determine the waste composition is generally based on the results of a single analysis of the waste. Trace metals concentrations in wastes typically vary widely.

b.	The data base incorporates many assumptions about the type and quantity of the wastes which would be available for incineration.

c.	Normalization and other data manipulation is required to place all data on a common basis. These manipulations are potential sources of variation.

Modeling of the behavior of metals in waste incinerators is still approximate. Much work is focused on refining the models, but it will be several years before more precise models are available. The current models are best used for predicting trends and estimating the impact of changing operating conditions. They are not as successful at predicting absolute emission rates.

F.	Speciation
	The model generates some very approximate predictions of the metal species which may form in the combustion system. However, because of the many assumptions required to produce these predictions they are not considered to be sufficiently reliable to be included in this analysis. The predictions are summarized in Attachment 3.1 for informational purposes only. Great care should be taken in any quantitative use of this information.

G.	Other Topics
	Three additional, specific topics are addressed. These are:

•	Evaluate the health risks associated with Al emissions;
•	Model the ratio of Cr(III) to Cr(VI) in the incinerator stack at the receptor; and
•	Evaluate the potential for trace impurities in the scrubber water to become stack emissions.

1.	Aluminum Toxicity
	The Combustion Engineering Work Group of the Peer Review Panel placed Al on its list of metals that should be included in the multi-pathway risk assessment. The group stated that Al might play a role in biological metabolisms or may interfere with the action of other metabolic metals. Though the toxicity of Al

is low, the group felt that the emissions would be high enough to warrant attention. A brief literature review was conducted to determine the relative importance of Al emissions due to its direct toxicity. While Al is one of the metals thought to catalyze the formation of dioxins, consideration of this indirect effect is not part of this assignment.

The major toxic effect of Al is from the inhalation of pure dust, which causes pulmonary fibrosis and neurological disorders. These disorders are also associated with Al exposure during renal dialysis. It is postulated that Al is associated with the formation of Alzheimer's disease although it is not thought to be causative on its own. Excess Al is deposited in bone and induces a form of anemia.

Some epidemiological studies have shown that all of the health effects mentioned above are more common in areas with higher levels of Al in the drinking water. Al is thought to be more biologically available in these areas. Usually the human gut excludes Al. The total quantity in the body is typically 25 mg and the daily intake varies from 10 to 100 mg. Antacids, deodorants and some processed foods contain high levels of Al. Additional exposure may arise from the use of aluminum cooking utensils.

Little appears to be known about the absorption of Al from inhaled dust. Incinerator emissions of Al would presumably be as fine particles. Fine particles themselves could be of significant concern but the aluminum on them would probably be in the form of aluminosilicates or oxides in which case the Al is not easily bioavailable. Furthermore, based on the refractory nature of aluminum compounds and the high control efficiency observed for entrained material, airborne concentrations of aluminum compounds from the incinerator system are expected to be extremely low at this facility.

It appears that Al emissions should be of lower priority than other metals but can not be neglected. The major problem in the assessment of Al related health risks is that little analytical data on the Al concentration in waste feeds are available. Without accurate feed data, prediction of emissions is difficult.

2. Chromium Valence State

The comments prepared by the Peer Review Panel referred to an EPA-developed model for evaluating the distribution of Cr between Cr^{+3} and Cr^{+6} in the stack and at the point of deposition. As a first step, the Kearney Team contacted Don Oberacker at the U.S EPA's suggestion as well as George Huffman, both of EPA/RREL in Cincinnati, Ohio. Neither person was aware of such an EPA model.

The Kearney Team did, however, identify a report produced by the Research Triangle Institute for the California Air Resources Board that presents the results from both laboratory and field studies on the conversion of Cr^{+3} to Cr^{+6} in the atmosphere. The half-life of Cr^{+6} was found to be on the order of one day.

The EPA reviewed the research efforts on this issue and suggested that no further effort be spent on searching for a speciation model. However, the modeling performed on this work assignment did predict the expected chemical form for each metal. Almost all of the stack emissions would be expected to consist of Cr^{+6} compounds based on strictly thermodynamic considerations. However, this depended heavily on the formation of CrO_2Cl_2. Data from studies of the corrosion of steel suggests that the oxychlorination of chromium produces $CrCl_2$ and $CrCl_3$ and that these reactions occur slowly requiring several hours to convert significant amounts of Cr_2O_3 to the chlorides. If CrO_2Cl_2 is excluded from consideration as for the predictions reported above, nearly all of the Cr present is predicted to be present as Cr^{+3} compounds. However, in the risk assessment all chromium emissions are conservatively assumed to be Cr^{+6}. It is also assumed in the risk assessment that no atmospheric reduction of Cr^{+6} would occur.

3.   Emissions from Scrubber Water

It is thought that emission of trace impurities from the scrubber water may contribute to the facility's total emissions. Data on scrubber water composition were requested for this activity, but only limited data were available. Due to lack of sufficient data, no further effort was applied to this issue. The U.S. EPA believes this to be a minor potential source of emissions because this feed stream normally consists largely of carbon-treated storm water runoff.

H.   Conclusions

Emission rates of the metals that were not measured during the trial burn are estimated. The estimates are based upon current understanding and scientific principles. Realistically conservative assumptions are made when required and are summarized in Table III-9. The predicted emissions are summarized in Table III-6. As with any theoretical model where many assumptions are required, the predictions should always be used with caution. Sensitivity analyses indicated that the predictions for most of the metals are not strongly effected by changes in the assumptions. The emission rates of a few metals are affected by each varied parameter, but with no clear trend toward increased or decreased predicted overall emissions. Additional data would help refine the emission estimates. Kinetic modeling should also be considered for future productions. A computer model such as the HCT program

developed at Lawrence Livermore National Laboratory may be useful in refining predictions of the chemical species formed.

Table III-1. Metals System Removal Efficiencies Measured During the WTI Trial Burn

Metals	System Removal Efficiency, percent			
	Run 1	Run 2	Run 3	Average
Sb	99.977	99.989	99.993	99.986
As	99.97	99.98	99.98	99.98
Be	>99.988	99.992	99.992	>99.991
Cd	99.993	99.986	99.982	99.987
Cr	99.9996	>99.9990	>99.9990	>99.9993
Pb	99.995	99.989	99.987	99.990
Hg	4.40	4.62	10.59	6.54

Source: May 1993, WTI Trial Burn Report

Table III-2. Waste Feed Compositions Used in the Modeling

| | Input Rate, mol/min | | | | | | | | |
| | Trial Burn | | | Annualized Average | | | Maximum Heat Input | | |
Element	Pumpable	Non-Pumpable	Total	Pumpable	Non-Pumpable	Total	Pumpable	Non-Pumpable	Total
Nonmetals									
C	-	-	3700	-	-	1180	-	-	4840
H	-	-	6600	-	-	2029	-	-	8320
O	-	-	551	-	-	166	-	-	681
N	-	-	0	-	-	40	-	-	165
Cl	-	-	766	-	-	43	-	-	175
F	-	-	0	-	-	1.29	-	-	5.27
Br	-	-	0	-	-	0.81	-	-	3.34
S	-	-	47.3	-	-	2.04	-	-	8.36
P	-	-	0	-	-	1.15	-	-	4.72
Si	21.6	84.5	106	23.6[b]	23.6[c]	47.2	94.3	94.3	189
Nontoxic Metals									
Ca	0	0	0	0.980	0.019	1.000	4.03	0.0772	4.10
K	0	0	0	0.177	0.024	0.201	0.709	0.0995	0.808
Na	0	0	0	0.143	0.480	0.623	0.585	1.97	2.56
Fe	0	0	0	4.75[d]	4.75[c]	9.50	19.0[d]	19.0[c]	38.0
Li	0	0	0	0.043	0.0004	0.0434	0.178	0.0015	0.180
Toxic Metals									
Al	25.6	0	25.6	4.90[e]	4.90[e]	9.80	19.6[e]	19.6[e]	39.2
As	0.385	0	0.385	0.031	0.00002	0.0311	0.128	0.0001	0.128
Sb	0.600	0	0.600	0.0035	0.0001	0.0036	0.0144	0.0004	0.0148
Ba	0	0	0	0.0728	0.00005	0.0728	0.291	0.0002	0.291
Be	0.252	0	0.252	0.0006	0	0.0006	0.0023	0	0.0023
Cd	0.787	0	0.787	0.0006	0.0152	0.0158	0.0024	0.0623	0.0648
Cr	6.2	18.5	24.7	0.0293	0.0004	0.0297	0.120	0.0016	0.121
Cu	0	0	0	0.0922	0.0022	0.0944	0.378	0.0090	0.387
Pb	3.67	0	3.67	0.0307	0.00007	0.0308	0.126	0.0003	0.126
Hg	0.0075	0	0.0075	0.00009	0.00006	0.00015	0.00017	0.00025	0.00042
Ni	0	0	0	0.0031	0.0023	0.00564	0.0128	0.00922	0.0220
Se	0	0	0	0.00041	0.0268	0.0272	0.00169	0.110	0.112
Ag	0	0	0	0.00075	0.00810	0.00885	0.00308	0.0322	0.0362
Tl	0	0	0	0.00312	0.00732	0.0104	0.0128	0.0300	0.0428
Zn	0	0	0	0.0288	0.0912	0.120	0.118	0.374	0.492
Water	-	-	2040	0	0	256	0	0	1050

a   From waste constituents (not from air).
b   Assumed 50 wt.-pct. of ash to be Si.
c   Assumed amount in non-pumpable streams (from ash) to be the same as in the pumpable streams, i.e., assumed same total ash feed rate in non-pumpable streams as in pumpable streams (5,300 g/min for maximum heat input case) and same concentration in ash. This was done because most of the non-pumpable streams were not analyzed for ash content.
d   Assumed 20 wt.-pct. of ash to be Fe.
e   Assumed 10 wt.-pct. of ash to be Al.

Source: May 1993 Trial Burn Report.

Table III-3. Comparison of Predicted Feed Rates with the Permit Limits

Metals	Permit Limit Type	Permit Limit Feed Rate (lb/hr)	Annualized Average Case[a] Feed Rate (lb/hr)	Annualized Average Case[a] Fraction of Permit Limit (%)	Maximum Heat Input[b] Feed Rate (lb/hr)	Maximum Heat Input[b] Fraction of Permit Limit %
Sb	Tier III[c]	9.65	0.0582	0.6	0.234	2.4
As	Tier III	3.81	0.309	8.1	1.27	33.3
Ba	Adj. Tier I[d]	260	1.29	0.5	5.30	2.0
Cd	Tier III	0.3	0.0007	0.2	0.003	0.9
Cr	Tier III	169	0.203	0.1	0.834	0.5
Cu	NA[e]	NA	0.793	NA	3.25	NA
Pb	Tier III	100.4	0.841	0.8	3.45	3.4
Hg	Tier III	0.2[f]	0.0027	1.4	0.011	5.5
Ni	NA	NA	0.0417	NA	0.171	NA
Se	NA	NA	0.285	NA	1.17	NA
Ag	Adj. Tier I	16	0.126	0.8	0.517	3.2
Tl	Adj. Tier I	1.6	0.282	18	1.16	73
Zn	NA	NA	1.04	NA	4.25	NA
Other Components						
Cl	NA	2700	201	7.4	823	30.5
Solid Waste[g]						
Feed Rate	NA	10500	285	2.71	1170	11.1

a   Assumes 24 hour/day, 365 days/year operation.

b   Higher heating value in waste profile used to determine total heat input rate for the annualized average case of 29.5 MBtu/hr. Maximum design heat input rate is 121 MBtu/hr, or 4.10 times higher than the average annual case. Thus, the maximum rates are obtained by multiplying the average annual rates by 4.10.

c   Tier III limits are assumed to be based on the average feed rate during the March 1993 trial burn, test condition 1.

d   Adjusted Tier I limits are based on an assumed dispersion coefficient of 1.5 μg/dscm/g/sec.

e   NA = Not applicable.

f   Calculated using the average feed rate during the March 1993 trial burn although little removal occurred and the emission rates were unacceptably high.

g   "Solid waste" is assumed to include wastes termed "solids" and "solids, solid/liquid mix" in the waste profiles.

Source: May 1993 Trial Burn Report.

**Table III-4. Classification of Metal Vapors Used
to Determine Control Efficiency**

Soluble Metals	Insoluble Metals
As	Hg
Sb	Al
Ba	Cr
Cd	Be
Cu	
Pb	
Ni	
Se	
Ag	
Tl	
Zn	

Table III-5. Control Efficiencies Used in Model

Material	Control Efficiency, %
Insoluble vapors	6
Soluble vapors	99.68
Fine Particles (<1 μm)	99.977
Coarse Particles (>10 μm)	99.9973

Calculated from May 1993 Trial Burn Report

Table III-6. Predicted Metals Emission Rates

Metals	Predicted Emission Rates Using Model, g/s		Predicted Emission Rates Using Trial Burn SREs, g/s	
	Annualized Average Basis	Maximum Heat Input Basis	Annualized Average Basis	Maximum Heat Input Basis
Tier III Metals				
Sb	1.7×10^{-6}	6.9×10^{-6}	1.0×10^{-6}	4.2×10^{-6}
As	9.0×10^{-6}	3.7×10^{-5}	9.0×10^{-6}	3.7×10^{-5}
Be	2.0×10^{-8}	8.1×10^{-8}	8.1×10^{-9}	3.3×10^{-8}
Cd	6.8×10^{-6}	2.8×10^{-5}	3.8×10^{-6}	1.6×10^{-5}
Cr	6.8×10^{-7}	2.8×10^{-6}	1.7×10^{-7}	7.1×10^{-7}
Pb	2.4×10^{-5}	1.0×10^{-4}	1.1×10^{-5}	4.3×10^{-5}
Hg	3.3×10^{-4}	1.4×10^{-3}	3.4×10^{-4}	1.4×10^{-3}
Other Metals				
Al	5.9×10^{-5}	2.4×10^{-4}		
Ba	3.7×10^{-5}	1.5×10^{-4}		
Cu	2.3×10^{-5}	9.4×10^{-5}		
Ni	1.2×10^{-6}	5.0×10^{-6}		
Se	1.1×10^{-4}	4.7×10^{-4}		
Ag	3.7×10^{-6}	1.5×10^{-5}		
Tl	8.2×10^{-6}	3.4×10^{-5}		
Zn	3.0×10^{-5}	1.2×10^{-4}		

Table III-7. The Observed Variation in the Control Efficiency of Selected Metals During the March 1993 Trial Burn

Class of Material	Control Efficiency, percent of weight	Standard Deviation
Insoluble vapors	6	4
Soluble vapors	99.68	0.2
Fine particles	99.977	0.006
Coarse particles	99.997	0.002

Table III-8. Possible Variation in Predicted Metals Emissions Due to Uncertainty in Input Data

Metal	Predicted Emission Rate, g/s		
	Based on Most Probable Data	Minimum	Maximum
Al	2.4×10^{-4}	2.2×10^{-6}	5.2×10^{-3}
Ba	1.5×10^{-4}	1.2×10^{-5}	1.9×10^{-3}
Cu	9.4×10^{-5}	1.0×10^{-7}	1.2×10^{-3}
Ni	5.0×10^{-6}	3.1×10^{-9}	6.3×10^{-5}
Se	4.7×10^{-4}	2.6×10^{-6}	4.7×10^{-3}
Ag	1.5×10^{-5}	1.2×10^{-6}	1.9×10^{-4}
Tl	3.4×10^{-5}	2.6×10^{-6}	4.7×10^{-3}
Zn	1.2×10^{-4}	9.5×10^{-6}	1.7×10^{-2}

Table III-9 Key Assumptions for Chapter III			
Assumption	Basis	Magnitude of Effect	Direction of Effect
Metals feed rates can be estimated based on one year of waste data	Best available data	high	either
Annual average waste feed rate should be adjusted to provide the maximum permitted heat input for the incinerator	Most conservative reasonable assumption. Produced highest metals feed rates which can be reasonably predicted.	high	either
Modeling is the most appropriate method for estimating the emissions of the metals which were not measured in the trial burn	Best available data	high	either
Thermodynamic equilibrium is maintained throughout the incineration and flue gas cleaning system	Most high temperature reactions are very fast. No detailed kinetic data are available	medium	either
All important compounds are included in the thermodynamic database	Best available data	medium	either
All elements in the incinerator are intimately mixed	Best available data	low	either
No condensed phase non-idealities occur	Best available data	medium	overpredict
The air to waste stoichiometric ratio which best characterized the region where metals vaporize is 1.0	Metals are most likely to vaporize in the hottest regions of the incinerator. These regions generally occur at the flame front. The stoichiometric ratio at the flame front is 1.0	low	either
Incinerator outlet temperature adequately characterizes the temperature to which the metals are exposed	Best available data	low	underestimate
$PbCl_4$ and CrO_2Cl_2 will not form	Field data indicates that these thermodynamically stable compounds are not present in significant quantities	medium	underestimate
All metals that vaporize and subsequently condense are found on particles 0.5 μm in diameter	Laboratory data and theoretical calculations indicate that condensing vapors concentrate on particles between 0.1 and 1 μm	low	either

Table III-9
Key Assumptions for Chapter III

Assumption	Basis	Magnitude of Effect	Direction of Effect
All pumpable waste is entrained	Pumpable waste is atomized to form drops which subsequently dry. The solid residuals form particles which are too small to settle out of the gas stream	low	overestimate
No non-pumpable waste is entrained	Non-pumpable waste is incorporated into slag. Most slag retained in incinerator by viscous forces.	low	underestimate
Chromium capture efficiency is an appropriate indicator of flue gas cleaning system's ability to capture coarse particles	Chromium is a refractory metal that modeling indicates will not vaporize significantly. Thus, chromium was probably present only on the coarse particles reaching the cleaning system	low	overestimate
Arsenic capture efficiency is an appropriate indicator of the flue gas cleaning system's ability to capture fine particles	As a volatile metal that will vaporize at any condition reasonably likely to occur in the incinerator and is expected to condense in the flue. Thus arsenic was probably present on only the fine particles reaching the flue gas cleaning system. The capture efficiency was the lowest measured in the trial burn	low	either
SO_x capture efficiency is an appropriate indicator of the flue gas cleaning system's ability to capture soluble vapors	SO_x will be present in the flue gases as a vapor. SO_x are soluble. The capture efficiency of SO_x is lower than other soluble vapors which were measured in the trial burn. Thus, use of SO_x is conservative	low	either
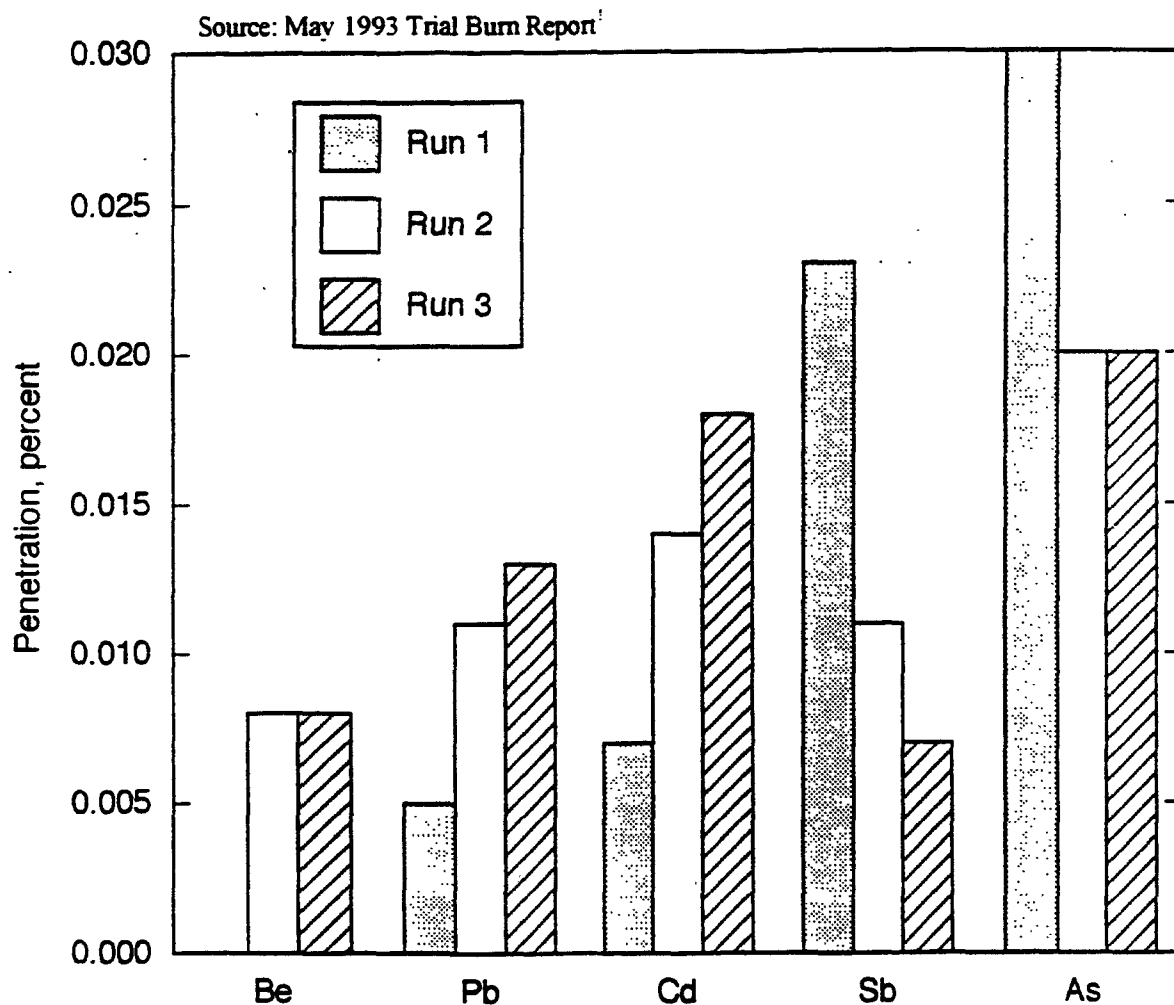
Figure III-1. System penetration observed during the WTI trial burn for As, Be, Cd, Pb and Sb. The metals are listed in order of increasing volatility.
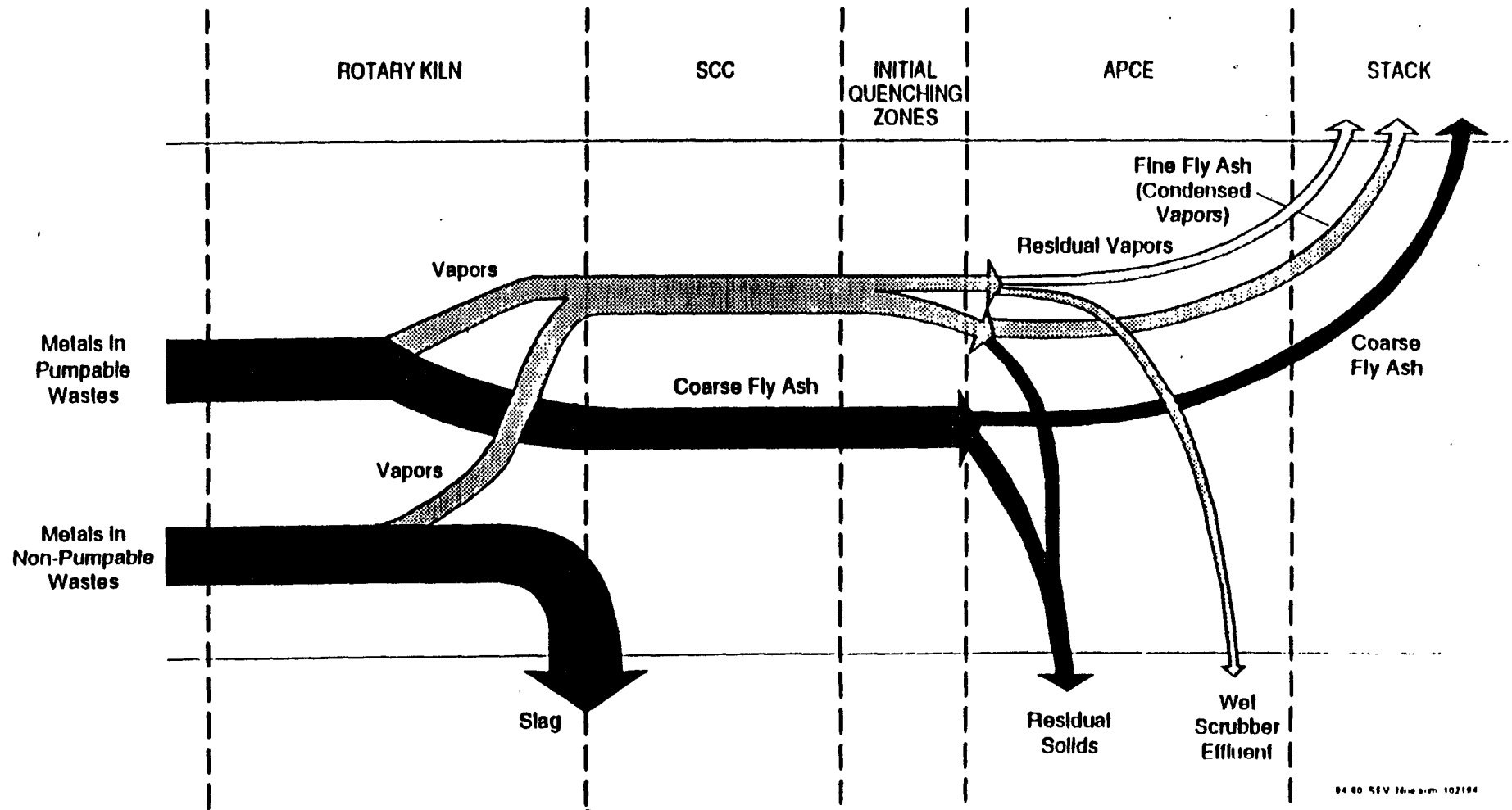
Figure III-2.   Pathways available for toxic metals in the WTI incinerator.
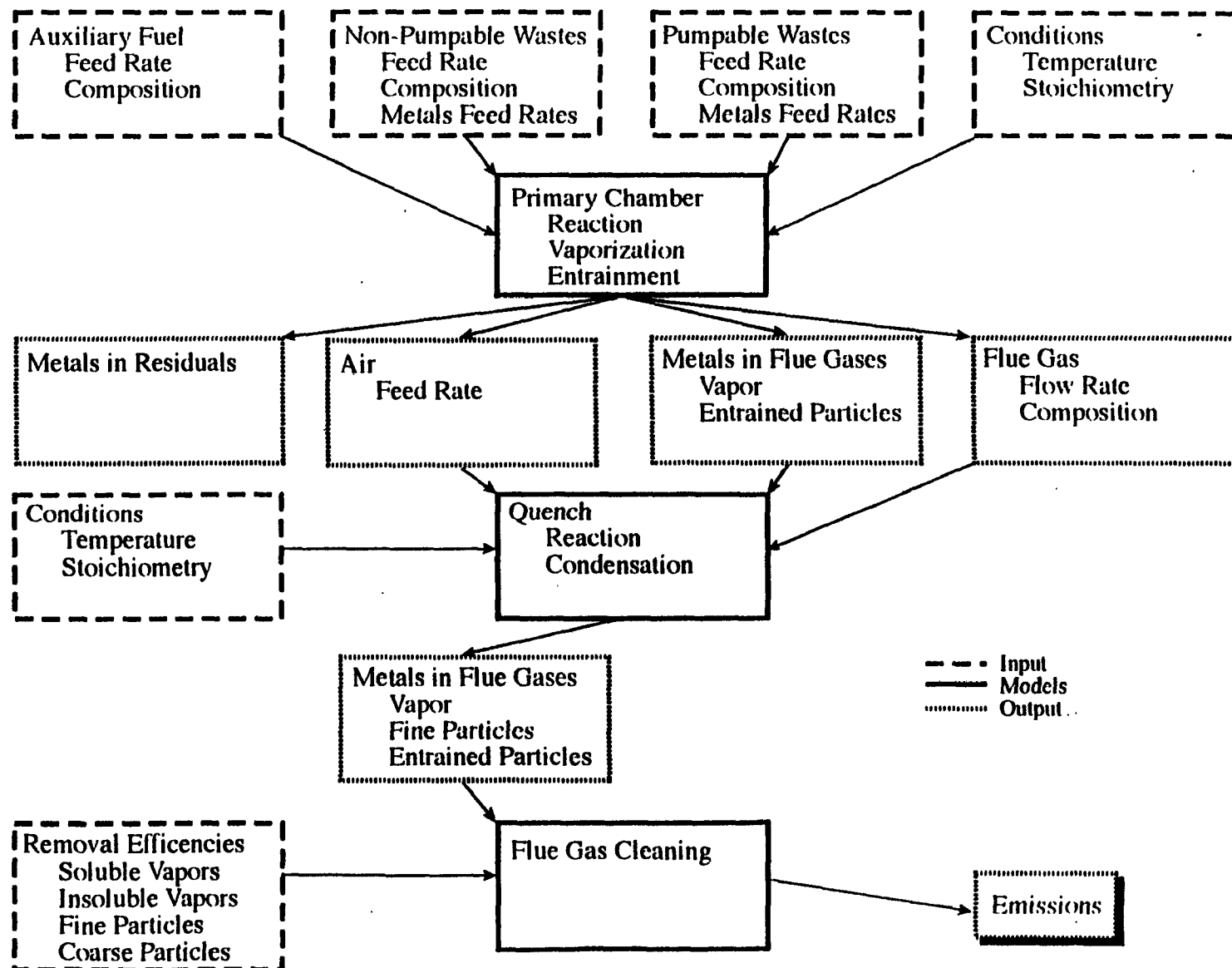
Figure III-3. Schematic diagram of modeling approach used.
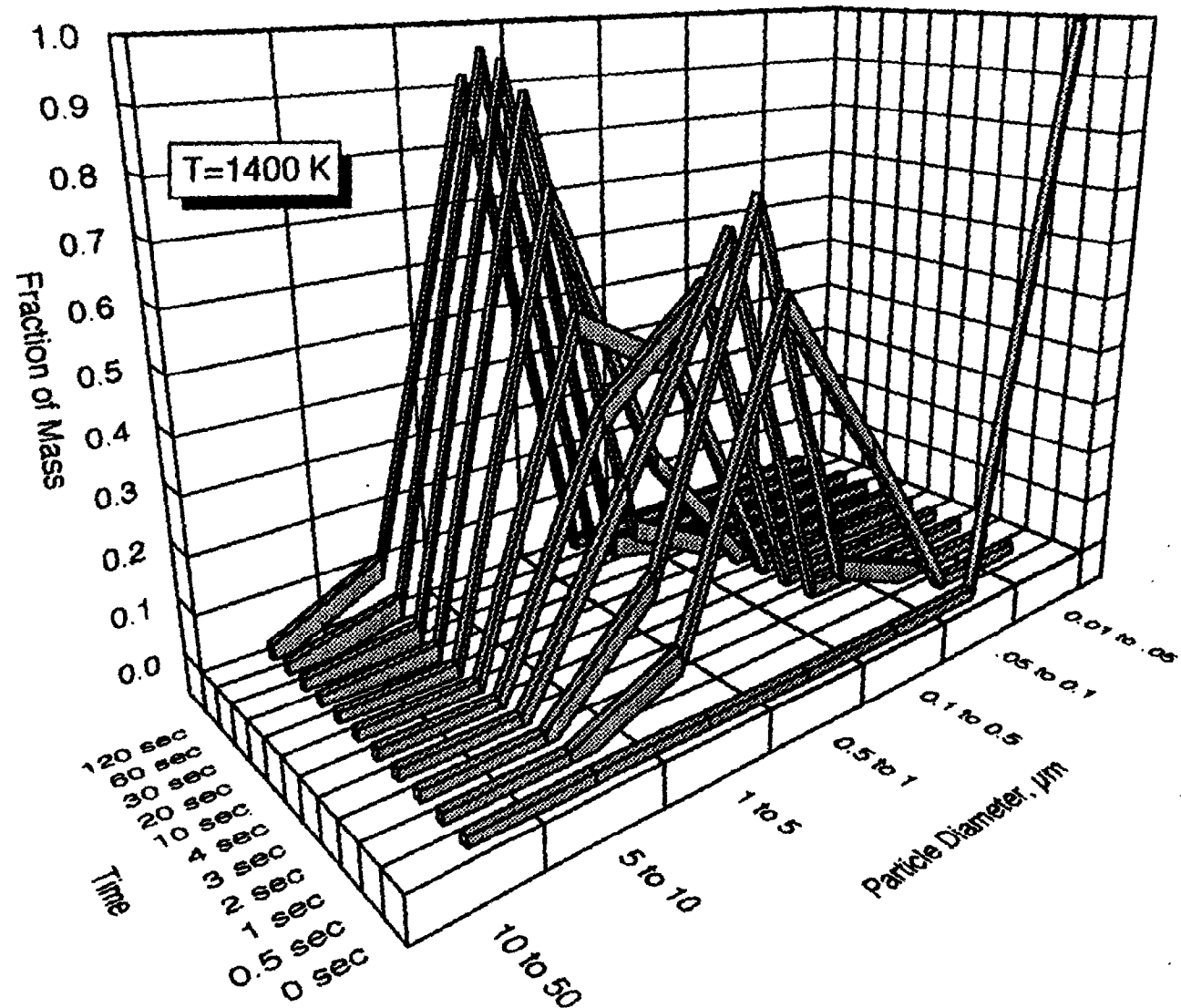
Figure III-4. The predicted evolution of the particle size distribution in 1400 K gases.
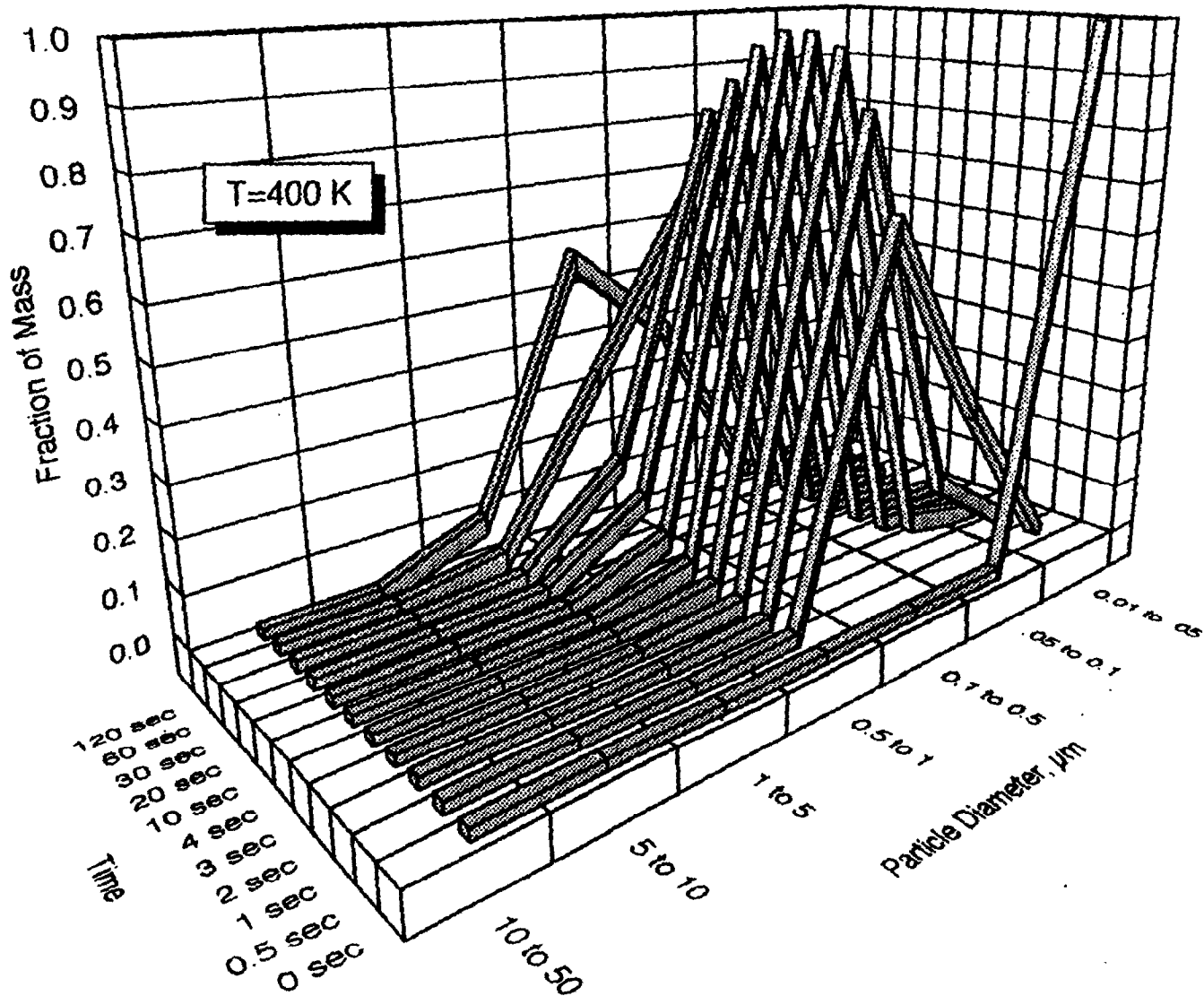
Figure III-5. The predicted evolution of the particle size distribution in 400K gases.
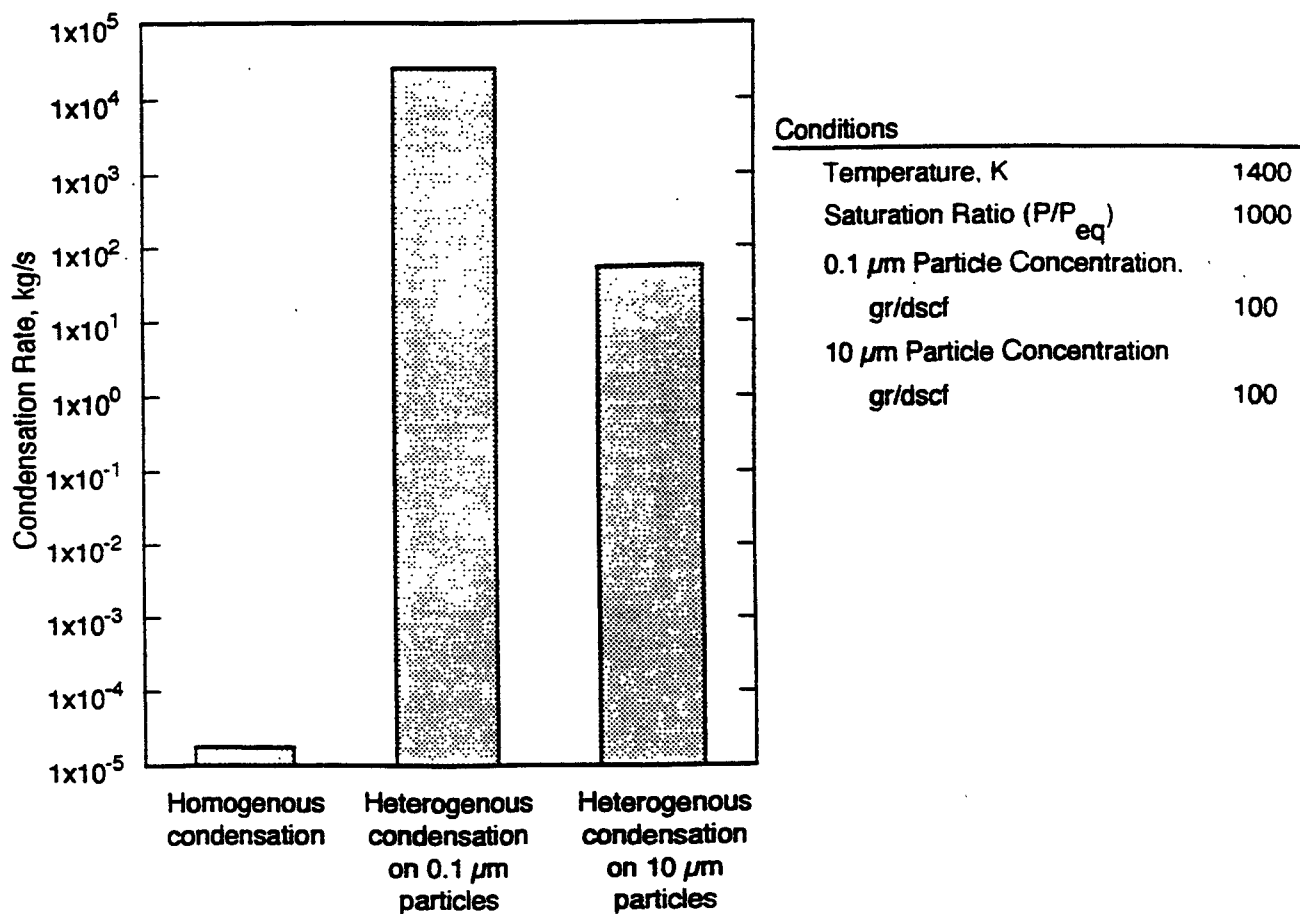
Figure III-6. Relative rates for homogeneous condensation and heterogeneous condensation onto 0.1 μm particles and 10 μm particles.
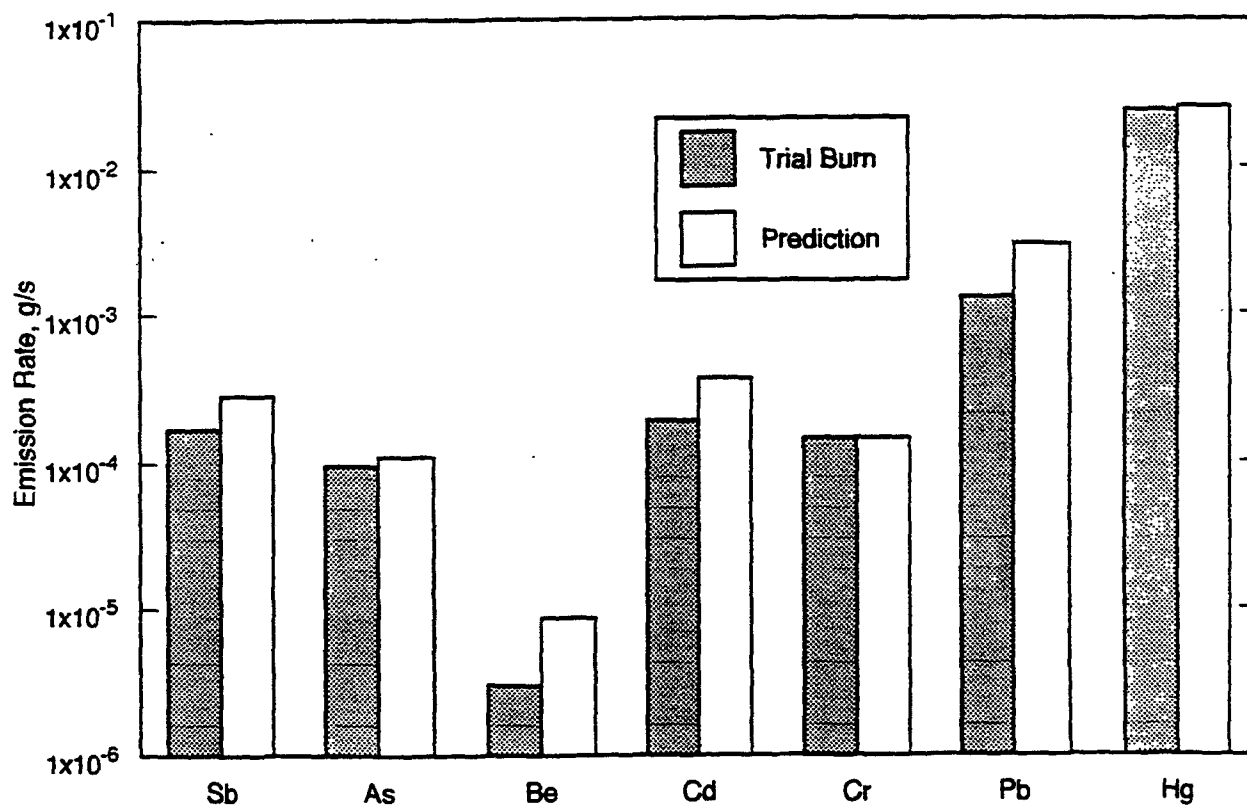
Figure III-7. Comparison of the model's predictions and the March trial burn results from the WTI incinerator.
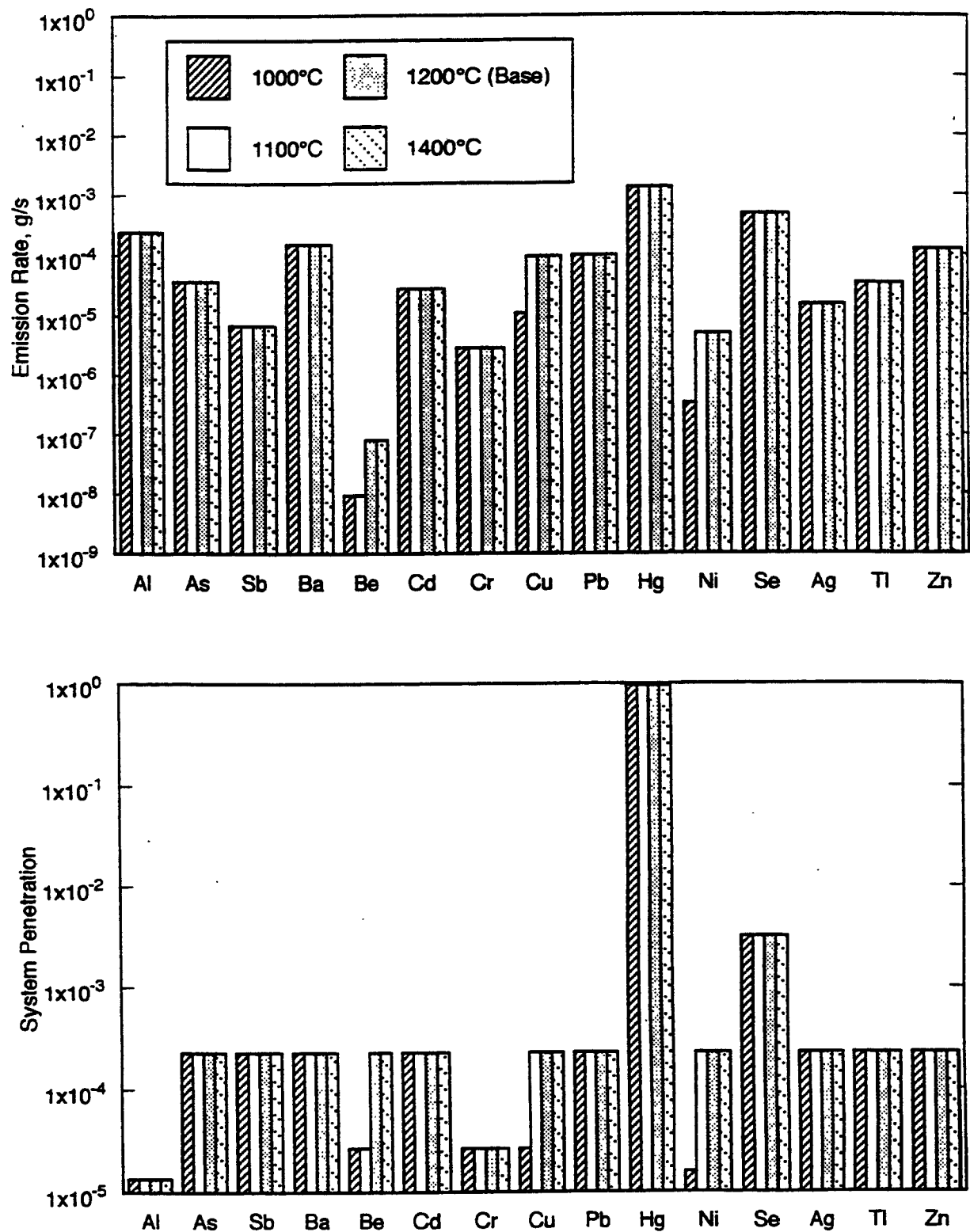
Figure III-8. The impact of temperature on the predicted metals emissions and the observed SREs.
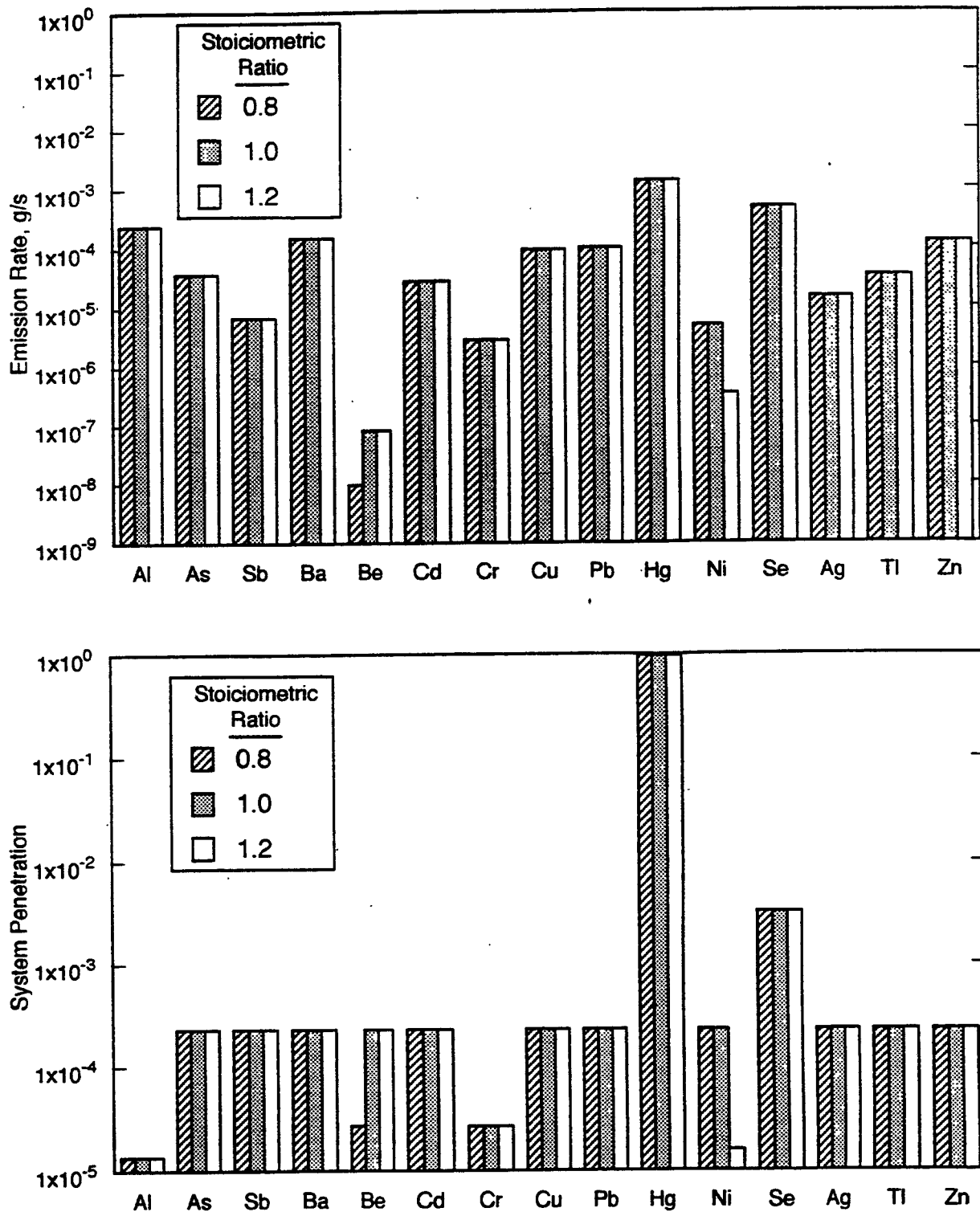
Figure III-9. The impact of the quantity of air used on the emissions rates and the observed SREs of the metals of interest.
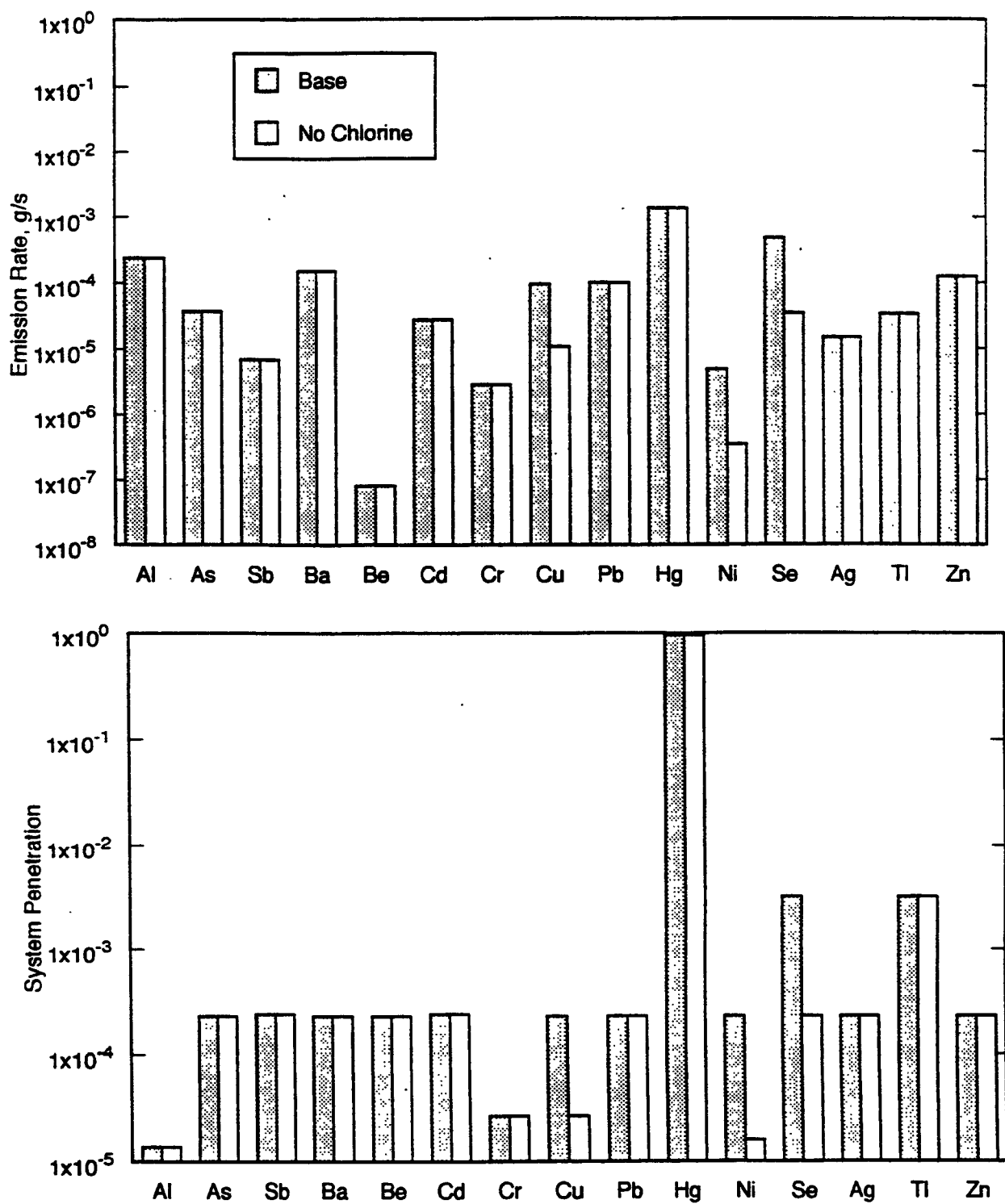
Figure III-10. The impact of chlorine on the predicted metals emissions rates and SREs.
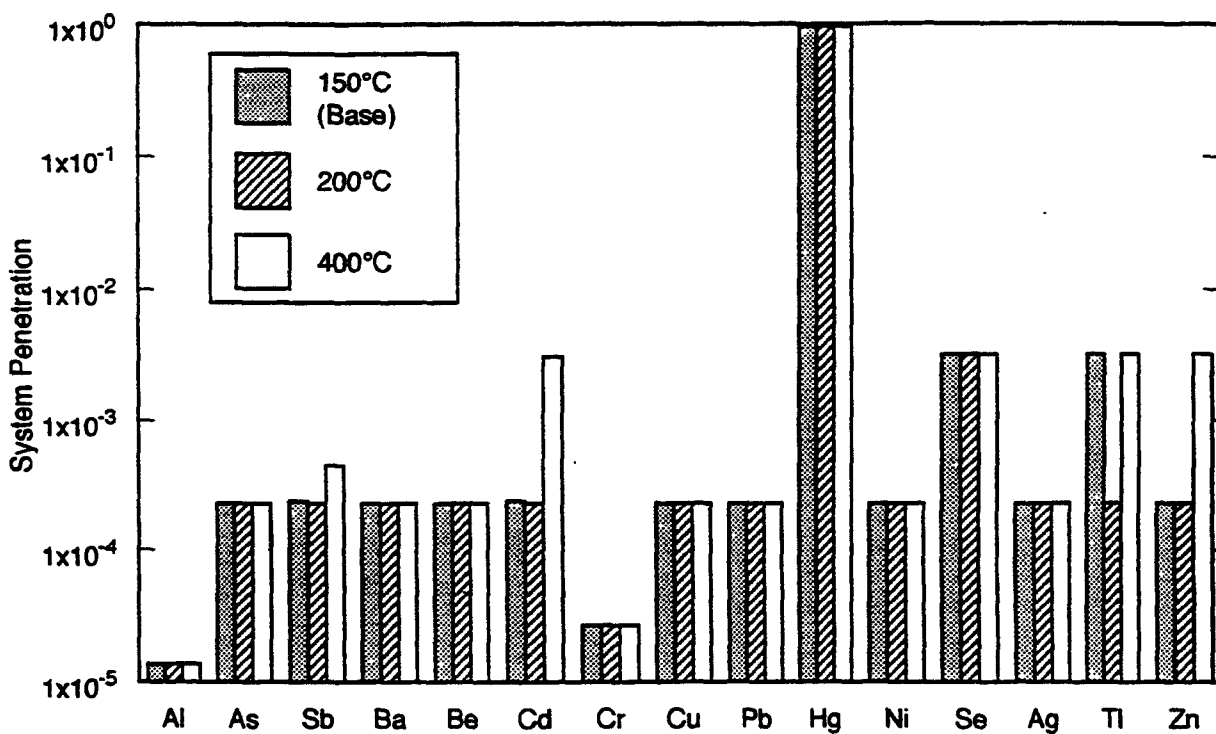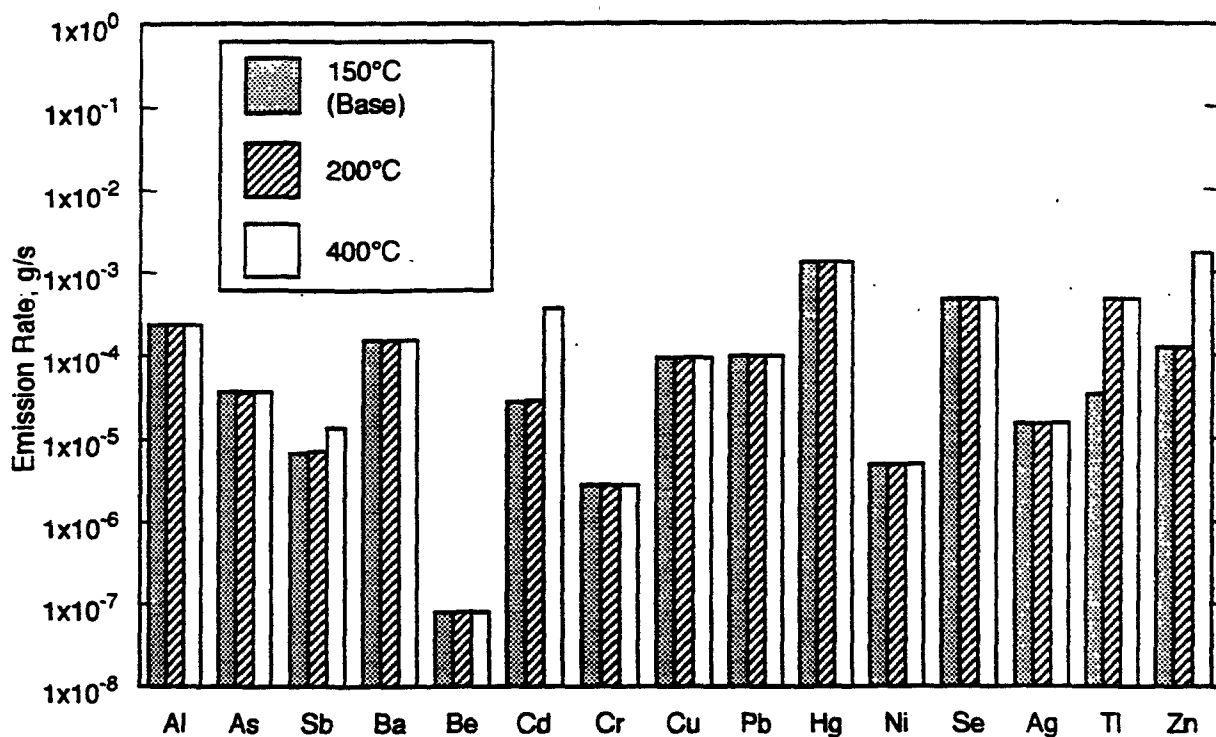
Figure III-11. The impact of quench temperature on the predicted metals emissions rates and SREs.
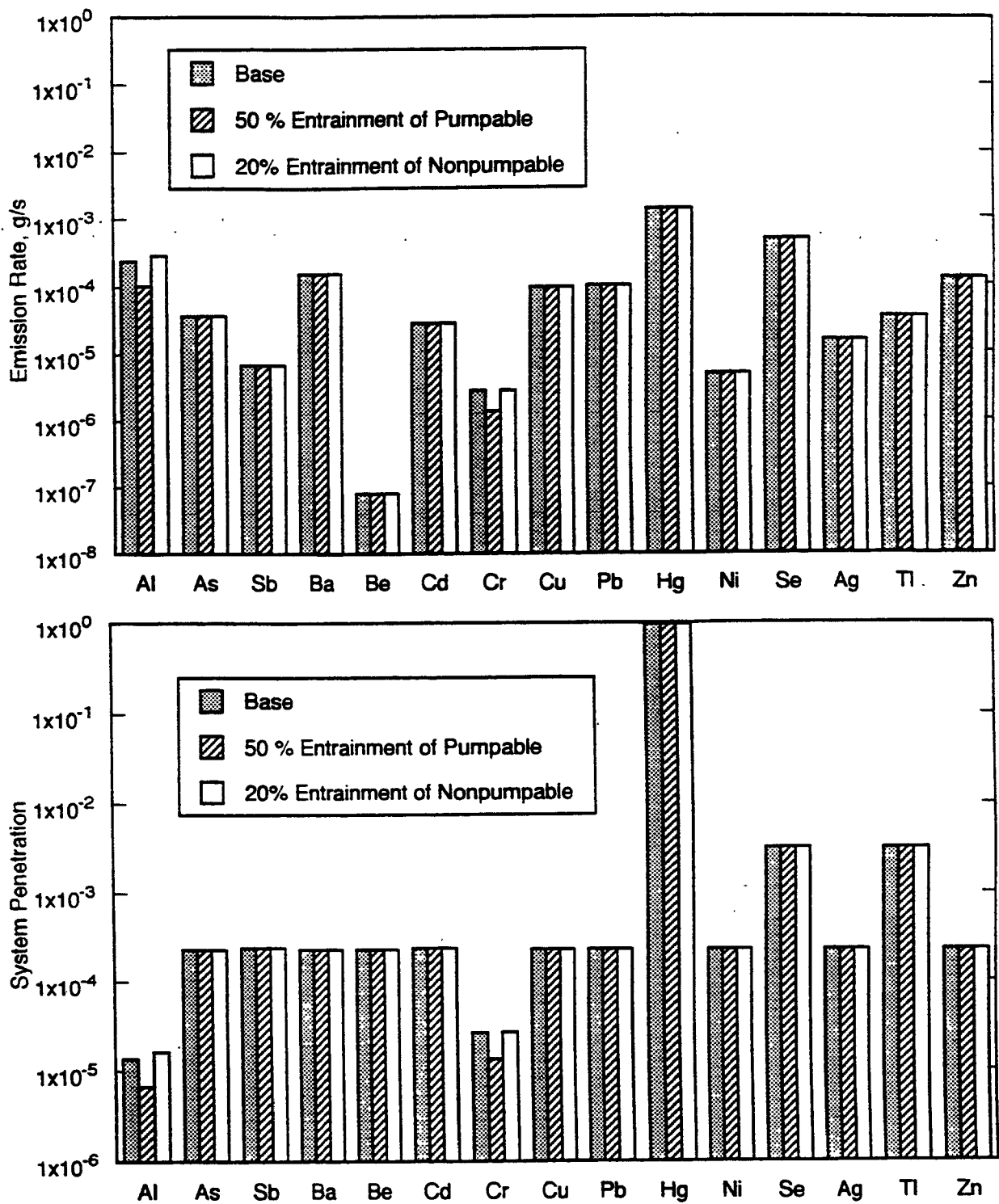
Figure III-12. The impact of entrainment rates on the predicted metals emissions rates and SREs.

CHAPTER IV. ESTIMATION OF ORGANIC EMISSIONS FROM THE WTI INCINERATOR

A. Introduction

This section describes the steps taken to estimate emissions of organic compounds from the WTI incinerator. At the time of the original WTI project plan (U.S. EPA 1993b) and Peer Review (U.S. EPA 1993c), there were very few stack test data available for nondioxin products of incomplete combustion (PICs) at WTI, and it was proposed to estimate these emissions for use in the risk assessment. While developing a viable estimation technique, the U.S. EPA also talked with WTI representatives about the importance of conducting actual stack testing for nondioxin PICs. In late August 1994, and again in December 1994, WTI did perform a very comprehensive series of PIC speciation tests, including a total of 16 test runs. When the results of the August 1994 PIC tests were received, the U.S. EPA decided to use these actual data in lieu of the estimates which were being prepared. However, it was decided that the estimates would still be important for filling in gaps in the August 1994 measured data, and for putting the measured data into perspective. Therefore, a master list of estimated emissions was assembled, and the methodology for this estimated list is described in this section.

The master list of estimated emissions is based partly on calculations from waste feed information, and partly on earlier and less detailed (and potentially less representative) test data obtained during the trial burn testing. The list of estimated emissions is subsequently used as a basis for calculating the possible magnitude of the potential "uncharacterized fraction" of nondioxin organic PIC emissions, an element necessary for the uncertainty analysis of this risk assessment.

. To the extent that the results of actual sampling and analysis (including detection limit values in nondetect situations) from the August 1994 test series are available, this risk assessment preferentially uses those actual values. In situations where an analyte was not detected during that series of tests, U.S. EPA assumes that emissions of that PIC exist at 1/2 the detection limit for the typical case, and that they exist at the full detection limit for the high-end case. Only when these data sources are not available for a particular hazardous constituent is information from the master list of estimated emissions employed in the risk assessment.

The results of the December 1994 PIC testing were not received in time to be numerically averaged into the risk assessment calculations. However, those data were reviewed and found to be comparable to the August 1994 data. A U.S. EPA compilation of the data from both those tests is available from Region 5.

The following discussion is divided into four sections. The first section deals with the approaches the U.S. EPA evaluated and eventually uses for creating the list of estimated PIC emissions from the WTI stack, and for estimating the potentially uncharacterized fraction. The second section addresses the related issue of potential effects of the WTI air pollution control devices on these emissions. The third section discusses the most appropriate way of estimating dioxin emissions for use in the risk assessment (dioxin/furan emissions were addressed separately because of the different formation mechanisms involved). The fourth and final section discusses uncertainties in the estimated data.

B.   Estimation of Organic Emissions

Estimating Emissions and Uncharacterized Fraction

Data on organic compound emissions that WTI reported as being quantitated during the trial burns are limited to eight compounds, plus dioxins and furans, as shown in Table IV-1. Specifically, there were four principal organic hazardous constituents (POHCs) and four products of incomplete combustion (PICs). During the trial burn, a test waste stream containing the POHCs was made up specifically for the purposes of a worst case test of the incinerator, and this resulted in a chemical composition that is not deemed representative of the annual waste profile for the WTI facility. Because of this, the measured POHCs in the stack gas are not necessarily realistic estimates of day-to-day emissions. But since the concentrations of PICs in stack gas are not as directly related to waste composition as are POHCs, the facility-specific trial burn PIC emission data are considered to be the reasonable estimates for the PIC compounds.

Total hydrocarbon (THC), as methane, was reported at slightly less than 1 ppm during the March 1993 trial burn test. If the maximum concentration values for the measured compounds on Table IV-1 are compared to the THC concentration, a large portion of the THC mass appears to be identified. However, one important factor needs further evaluation because it might change this conclusion significantly. Specifically, the response factor of chlorinated compounds to the flame ionization detector (FID) used for THC measurement is lower than for hydrocarbons (e.g., carbon tetrachloride has about half the THC response of methane). If most of the PIC emissions happen to be chlorinated compounds, the THC values might be expected to be biased low. Related to this concern is the observation that the concentrations of carbon tetrachloride and tetrachloroethylene varied widely across the different trial burn test conditions at WTI, but the observed variation in the THC values was very small. This issue will be discussed later in this Chapter.

Because so few PICs were identified during the March 1993 trial burn, several approaches were considered to further identify or estimate emission levels of specific

compounds. Perhaps the simplest approach would have been to assume that all of the organic mass identified by the THC analyzer comprises the most toxic species, i.e., dioxins/furans. This is the most conservative approach, but it would also be extremely unrealistic and would likely result in an overestimation of the risk by at least several orders of magnitude. The most accurate technique for further identifying PICs would be additional stack sampling and analysis for a long list of target compounds, but this approach is very resource intensive and time consuming. In addition, it is likely that even the best sampling and analytical program would still not provide complete knowledge of all of the organic components of the stack emission. Within this range of approaches, several additional approaches were considered to provide a more realistic estimate. These approaches are described below.

The first approach was an idea suggested by the Peer Review Panel to gather historical waste composition data from WTI and to apply combustion chemistry knowledge to predict PICs that would be emitted. This approach would require a specific model or procedure which could both predict the compounds emitted and estimate the emission rates.

This approach was investigated further. Phone contacts were made with incineration or combustion experts to solicit their views on estimating PIC emissions from knowledge of the waste composition or by other methods. The experts contacted included William Linak, EPA/AEERL; Robert Thurnau and Gregory Carroll, EPA/RREL; and Daniel Chang, University of California/Davis. The preliminary consensus from these experts was that no method had, to date, been shown to quantitatively predict PIC emissions from knowledge of waste composition. Most of these respondents suggested that specific data for the facility, if available, or historical data on hazardous waste combustion might provide the best basis for emission estimates.

This investigation did identify data where the identity (although not the quantity) of several PICs had been predicted from knowledge of waste burned in research tests (viz., one full-scale hazardous waste incinerator and an EPA pilot-scale incinerator (U.S. EPA 1991, U.S. EPA 1992).) Although sampling and analysis did indeed detect these predicted PICs in the incinerator stack gas, the specific compounds predicted were those PICs generally regarded as being very common in combustion systems. These data suggested that it may be possible to predict the likely identity of several major PICs based on major waste constituents, but it was concluded that this technique would not be a better predictor than

simply using known common PICs. Also, the specific procedure used for these predictions was not reported.

A second approach which the U.S. EPA and its consultants evaluated was the evaluation of raw data from the gas chromatograph/mass spectrometer (GC/MS) analyses performed as part of the WTI trial burn. These analytical data would be used to further evaluate the presence or absence of compounds of interest by allowing the U.S. EPA to determine if the GC/MS instrument recorded any additional evidence of volatile and/or semivolatile compounds in the stack gas samples. For compounds present in high enough quantities, a rough estimate of emission rates could potentially be determined. For compounds not found, minimum quantitation limits could be estimated, allowing the assumption that the compounds are not present above a specified level.

A second potential use of the GC/MS data would be to estimate the portion of the mass associated with different classes of compounds. If a specific percentage of the mass could be associated with a class of compounds that seldom contains toxic compounds, then this percentage of the overall mass of organic emissions could be deducted from the total mass assumed in the risk assessment. Although this approach would not result in a complete characterization of all organic compounds emitted, it could potentially allow more realistic assumptions to be made about the unidentified mass.

Because a complete file of the raw GC/MS data could not be obtained within the time available, the GC/MS data approach was only partially implemented. The most important information to come from this element of the evaluation was an estimate of the practical detection limits. These were later used in estimating PIC emissions.

A third approach which the U.S. EPA evaluated was the use of available historical emission data from other hazardous waste incinerators. This would not provide a complete site-specific characterization, but it was thought that it might allow more realistic assumptions than would the use of certain more theoretical approaches. This approach was eventually deemed less reliable than the other methods and was therefore dropped.

Based on this initial analysis, it was decided to take the following approach to develop an estimate of the organic nondioxin PICs and to also estimate the potential magnitude of the "uncharacterized fraction" of the total mass of organic emissions.

1.   Estimated PIC Emissions

The trial burn reports for the March 1993 and the February 1994 (retest of condition 2) trial burns indicate that of the PICs identified for sampling and analysis, only benzene, chloroform, and tetrachloroethylene are detected in quantifiable

amounts.[1] In addition to these measured PICs, WTI submitted summary data from an additional PIC analysis which had been conducted on samples collected during the February 1994 trial burn. These data include results of GC/MS analysis of VOST and semivolatile samples collected during the retest. The average of runs 2, 3, and 4 of this trial burn is used to determine the emission rate for each analyzed compound under test condition 2[2]. Nondetect compounds are assumed to exist in the stack gas at half of the detection limit. While WTI provided detection limits for the volatile compounds, detection limits are not reported for the semivolatile compounds. Detection limits for these compounds are estimated at 2 μg based on back-up GC/MS data files received from WTI (Sigg 1994b).

Residual POHC emissions are calculated based on the annualized waste profile and on the destruction and removal efficiency (DRE) measured during the trial burns. This technique is essentially a simplified version of an approach suggested by the Peer Review Panel. The annualized waste profile discussed in Chapter II is used to estimate emission rates of each compound on an annual basis, after that profile is corrected[3] to reflect projected operation at full thermal capacity 365 days per year and 24 hours per day. Of these compounds, only the compounds that are on the U.S. EPA's list of target PICs (U.S. EPA 1994 and Mercer 1994) are considered in calculating residual emissions. Estimated emissions are calculated in grams per second (g/s). For those organic compounds whose emissions were estimated using the waste profile data base, the annualized volume of each compound is adjusted upwards by a factor of 4.1 to reflect maximum throughput of waste through the incinerator.

Of the three test conditions in the March 1993 trial burn, the DREs for condition 2 are lowest[4], and these values are also slightly lower than the DREs

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[1] Of the three test conditions for the March 1993 trial burn, condition 2 (a low kiln temperature test) had the highest emissions for these three compounds. Condition 2 of the March 1993 trial burn demonstrated higher emissions of tetrachloroethylene than the February 1994 retest of condition 2. The February 1994 retest had higher emissions of benzene, and emissions of chloroform were about the same for both tests.

[2] Because run 1 was stopped prematurely, the U.S. EPA judged that the run 1 test results might not be representative.

[3] This correction was necessary in order to "scale up" the waste feed rate to full capacity from the relatively small quantity actually received during the first year of operation.

[4] In fact, it was condition 2 of the March 1993 trial burn where one of the POHCs failed to achieve the required DRE of 99.99% during two of the three test runs.

measured during the February 1994 retest of condition 2. The average of nine values (three runs, three POHCs) from condition 2 measured during the March 1993 trial burn is used to represent a reasonable worst case DRE. This DRE is then applied to the emission rates of organic compounds identified in the waste profile (and included on the U.S. EPA's target list of PICs) to calculate residual emissions of these compounds.

A compound specific estimate is made for 129 of the compounds on EPA's list of target PICs (including PCDD/PCDF TEQ as one compound). The breakdown of the number of compounds selected from each source of data is shown in Table IV-2 below. Stack gas concentrations that correspond to the estimated emission rates presented in Attachment 4, range up to 400 ng/L for tetrachloroethylene. These values are in the same range as historical measurements for hazardous waste incinerators (USDOC 1984).

Attachment 4 to this Appendix presents the complete list of compound-specific emission rates that were compiled from the various sources along with the final estimated emission rate for each compound.

2. Estimation Procedure for the Uncharacterized Fraction

The approach to estimating the potential magnitude of the uncharacterized fraction of organic PIC emissions is based on comparing the total mass of organic compound emissions, as derived from recorded total hydrocarbon (THC) values, with the mass that would result from the emissions estimated in the above subsection. Total hydrocarbon emissions measured during the trial burn are mathematically increased to account for compounds thought to be biased low by the design of the typical THC analyzer, and the resulting values are believed to be a reasonable conservative (high-end) estimate of total mass of organic compounds.

Total hydrocarbon emissions measured during the March 1993 trial burn are about the same for all three test conditions. The emissions range from 0.68 ppm to 0.89 ppm, measured as methane. The average of the three test runs under condition 2 (0.70 ppm) is used in this analysis to be consistent with the earlier selection of condition 2 as the worst case for DRE. Total hydrocarbon measurements are only available from one other test (viz., the February 1994 trial burn retest of condition 2). The THC recorded during the February 1994 test is much lower than 0.70 ppm, and it is therefore judged more conservative to use the values recorded in March 1993.

The selected THC value is reported in units of ppm and pounds per hour of methane in the trial burn report. This mass/time value is converted to units of grams per second (g/s), converted to the average molecular weight of compounds in the

emissions estimate (versus the molecular weight of methane, the calibrating gas), and adjusted to account for known differences in response of the flame ionization detector (FID) to the various organic compounds in the emissions list when compared to that of methane. The lb/hr values reported for the THC monitor are calculated from a volume (molar) concentration that is directly measured by the monitor and the molecular weight of the compound (methane) used to calibrate the monitor, which converts the value to a mass rate. To convert this value to lb/hr of the estimated emissions, the lb/hr value, as methane, is multiplied by a factor representing the molecular weight of the estimated emissions divided by the molecular weight of methane. An additional correction is necessary for FID response because an FID responds differently to different compounds depending on the molecular structure of the compound (U.S. EPA 1979). To simplify the molecular weight conversion and FID response correction, they are based on the molecular weights and structures of the compounds that make up 90 percent of the mass of emissions. The result is an increase in the THC emission rate by a factor of 3.08, (of which 2.72 is the molecular weight correction) relative to the actual measured value.

Furthermore, the THC value in g/s is increased by a factor of 2.87 to account for the organic compound mass that is typically not measured by such a THC monitor. The THC monitoring system used at WTI, like most such monitors, has an ice temperature condensate trap on the sample line. The factor of 2.87 is based on research findings that THC measurements using such a THC monitor are typically less than half the measurements obtained using a simultaneous alternate total organic mass measurement procedure. This difference is explained in the findings of that research as being largely due to volatile compounds, likely water soluble, that condensed with water in the condensate trap on the sampling line for the THC monitoring system (U.S. EPA 1988).

The result of this analysis is that the uncharacterized fraction is approximately 60 percent[5] of the total mass of organic stack emissions. Figure IV-1 presents the possible components of the organic compounds emissions estimate. The first column in Figure IV-1 shows the total mass of organic compound emissions that is

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[5] It should be emphasized that because the THC value used in this analysis has been conservatively increased by several factors to account for potential instrument bias, and because it has been observed at other facilities that much of the THC recorded by an FID-type monitor is due to non-toxic methane and ethane, this estimated total organic emission rate would represent a reasonable upper bound on the emissions of toxic PICs. While it is unlikely that the fraction of uncharacterized toxic emission is this high, such an upper bound is useful for the purposes of examining uncertainty.

represented by the adjusted THC value. This total organic mass is divided into several components for the purpose of this analysis, and these are qualitatively described in the second column of Figure IV-1. These components include estimated emissions from residuals of waste compounds, PIC emissions measured during the trial burn, de minimus estimates for compounds below detection during the trial burn, the potential uncharacterized mass fraction, and dioxin and furan emissions measured during compliance tests. The third column in Figure IV-1 presents the number of compounds based on each category. The fourth column presents the percent of total mass represented by each category of compounds in the emissions estimate.

At the time when this evaluation was originally underway, the uncharacterized fraction was conservatively assumed to be similar in composition and potency to the known carcinogenic fraction of the nondioxin PICs. This approach would have included multiplying each of the estimated emission rates for each identified nondioxin carcinogen by a correction factor (sometimes referred to as "prorating") to bring it up to a level which would account for the "unknown" mass. For example, if 50 percent of the total mass of organic emissions was unaccounted for, the estimated emission rate for each identified carcinogen would have been multiplied by 3. However, as this evaluation developed and evolved, it was eventually decided to not prorate the emissions in this way because it would overemphasize carcinogenic impact and ignore toxic (i.e., non-carcinogenic) impacts. Therefore, the decision was made to instead discuss the impacts of any potentially unknown mass in the uncertainty section of the risk assessment.

Figure IV-2 presents a detailed flowchart of the steps taken in estimating PIC emission rates and in comparing this estimate to the adjusted THC value.

C.   Effect of Control Device

In evaluating organic compound emissions from the WTI facility, it is important to consider the potential effect of the control device on these emissions.

The effect of the control devices on nondioxin organic compounds is most associated with two factors. First, particle removal will reduce the emissions of heavier organic compounds that may have condensed on particles. Second, most organic compounds have the ability to adsorb onto the activated carbon which is injected for dioxin control. Neither of these factors can easily be quantified, but both factors could result in a reduction in PIC emission rates.

No data are known at this time which show the amount of removal for specific organic compounds (except dioxin) that might result from carbon injection. Some data, however, are found for THC levels on a medical waste incinerator equipped with carbon

injection in a spray dryer/fabric filter air pollution control system (U.S. EPA 1992). Data are available before and after the control device for three test runs with and without the carbon injection. Inlet levels of THC ranged from 1 to 6 ppm. Outlet levels are generally about half the inlet levels, either with or without operation of the carbon injection system. These data show that there is no large removal effect of a carbon injection system on the bulk of combustion THC emissions. Since no other data are found which could be used to evaluate the potential removal of specific nondioxin compounds by the control device, a conservative assumption of no removal is used in this risk assessment.

It is not deemed necessary at this point to evaluate the theoretical effect of the air pollution control train on the emissions of dioxins/furans, because the effectiveness of the pollution control system in collecting these materials is demonstrated at WTI through extensive stack sampling and analysis.

D. Emissions of PCDD/PCDF

Estimating polychlorinated dibenzodioxin/polychlorinated dibenzofuran (PCDD/PCDF) emissions is discussed separately because the factors that affect the emission levels are significantly different than those for most other organic compound PICs. In particular, it is presently believed that most PICs are formed in the combustion chamber of an incinerator, but that most PCDD/PCDFs are formed in the ductwork and pollution control devices which follow the combustion unit.

As with estimating emission levels for other compounds, the best estimates will be based on measured emission levels.

When this risk assessment project first got underway, there was insufficient emission data to determine whether the newly installed enhanced carbon injection system (ECIS) would reliably reduce the emissions of dioxins and furans. Since that time, additional testing has been performed. As of this writing, there have been 37 dioxin/furan test runs since the installation of the ECIS.

Because the WTI facility will be operating with the ECIS in place, and because repeated testing has confirmed the effectiveness of the ECIS, the risk assessment is based on emissions data from the post-ECIS installation tests. Specifically, average emission rates for the 17 dioxin and furan congeners (see Volume III, Table III-2) are calculated as the arithmetic mean of the emission rates measured in the 26 post-ECIS installation test runs conducted between August 1993 and August 1994. Dioxin and furan congeners not detected during a specific run are assumed to be present at one-half of the detection limit for the congener during that run. It is believed that in this way, emissions of dioxins and furans will not be understated.

E.   Uncertainties

Figure IV-2 presented the procedure used to estimate the emission rates for organic compounds for the WTI incinerator. Figure IV-3 is identical to Figure IV-2, except that several data sources and steps in the procedure are numbered. These numbers correspond to the key assumptions listed in Table IV-3. For each factor in Table IV-3, the magnitude of effect is categorized as low, medium, or high.

The types of key assumptions are exemplified by the two factors identified relative to item 1 in Table IV-3 (THC data) which may lead to uncertainty in the analysis. The first factor is the representativeness of the incinerator operation during the test when the THC data were collected (i.e., does long term operation differ from operation during the test, such that the long term THC data would differ from the value used for the emissions estimate?) The second factor is the uncertainty associated with the measurement method. Most of the factors in Table IV-3 are similar to these two factors.

The measurement uncertainty associated with emission rate estimates for compounds reported as not detected in analytical data sets (items 7 and 9) are judged high. This is because the true value could range from zero to the detection limit; an infinite factor. These emission rates, however, are very small and may not be significant. The other factors judged to have high uncertainty are items 10 and 14. The uncertainty associated with these items relates to the uncertainty of identification of compounds, not to the magnitude of the emission rate. Uncertainty associated with identification of compounds is likely the greatest area of uncertainty in the organic compound emissions estimate.

TABLE IV-1. POHCs, PICs, AND THC MEASURED
DURING THE WTI TRIAL BURN

Analyte	Concentration range, ng/L
POHCs:	
Monochlorobenzene	<2.5
Carbon tetrachloride	4.4-220
Trichloroethylene	<2.5
1,2,4-Trichlorobenzene	0.64
Identified PICs:[a]	
Benzene	5.7-39
Chlorobenzene	5.3-35
Tetrachloroethylene	<2.5-490
Methylene chloride[b]	<2.5-39
SUBTOTAL (POHCs and PICs):	<17-820
THC (as methane):	450-590 (0.68-0.89 ppm)

[a]Target PICs included seven compounds (three
volatile compounds), plus an additional
12 compounds in the class of tentatively
identified compounds (TICs). Only compounds
which were detected/identified are included.
[b]Designated as a TIC.

Table IV-2

Sources of Emission Rates

Source	No. of values
Estimated emissions from residuals of waste compounds 2*--DREs applied to waste profile data, DREs from condition 2 of 3/93 trial burn	54

PICs measured during trial burn
  1A*--Condition 2 of 3/93 trial burn
  1B*--2/94 retest of trial burn condition 2
  3A*--Other volatile PICs, 2/94 retest of condition 2
  4A*--Other semivolatile PICs, 2/94 retest of condition 2
 	
Total
	
	2
	1
	12
	_5_
	
	20

De minimus estimates for compounds below detection during trial burn
  3B*--Other volatile PICs, 2/94 retest of condition 2 (nondetected)
  4B*--Other semivolatile PICs, 2/94 retest of condition 2 (nondetected)
 	
Total
	
	14
	40
	
	54

Total dioxins and furans measured during compliance tests, TEQ	1

*--Designation used in Attachment 3.

	TABLE IV-3 Key Assumptions for Chapter IV		
Assumption	**Basis**	**Magnitude of Effect**	**Direction of Effect**
THC values are representative of incinerator operation and appropriate method of measure was used(1)	Best available data	medium	variable
Factor accurately reflects sample loss(2)	Best available data	low	variable
Factor accurately reflects instrument response (3)	Best available data	low	variable
Trial burn data (Condition 2 of 3/93) are representative of incinerator operation and waste composition and appropriate method of measurement was used (4)	Conservatively high values selected from best available data	medium	variable
Trial burn data (Condition 2 of 2/94) are representative of incinerator operation, waste composition and appropriate method of measurement was used (5)	Conservatively high values selected from best available data	medium	variable
Semivolatile and volatile PICs reported (detects and nondetects) on 7/1/94 are representative of incinerator operation and waste composition and appropriate method of measurement was used (6,7,8,9)	Conservatively high values selected from best available data	medium to high	variable
Waste profile database is representative of compounds in waste stream (10)	Best available data	high*	variable
DREs from 3/93 trial burn are representative of incinerator operation and appropriate method of measurement was used (11,12)	Conservatively high values selected from best available data	medium to low	variable
Waste profile database is representative of concentrations of targeted compounds (12)	Best available data	medium	variable

TABLE IV-3 Key Assumptions for Chapter IV			
Assumption	Basis	Magnitude of Effect	Direction of Effect
Dioxin/furan data from 8/93 test are representative of incinerator and APC operation and waste composition and appropriate method of measurement was used (13)	Conservatively high values selected from best available data	medium to low	variable

*High relative magnitude but small absolute magnitude

Total Mass of Organic Compound Emissions	Categories of Compounds in Emissions Estimates	Number of Compounds	Percent of Total Mass
	Estimated Emissions from Residuals of Waste Compounds	54	20.9
Total Hydrocarbons (THC) Measured During Trial Burn*	PICs Measured During Trial Burn	20	19.9
	Deminimus Estimates for Compounds Below Detection During Trial Burn	54	0.6
	Unknown Fraction Assumed Similar in Composition to Known Carcinogenic Fraction	Unknown	58.6
	Dioxins and Furans Measured During Compliance Tests	Tetra through Octa Congeners	2.3E-6

*Reported value increased to account for compounds not detected or not accurately measured.

Figure IV-1. Components of organic compound emissions estimate.
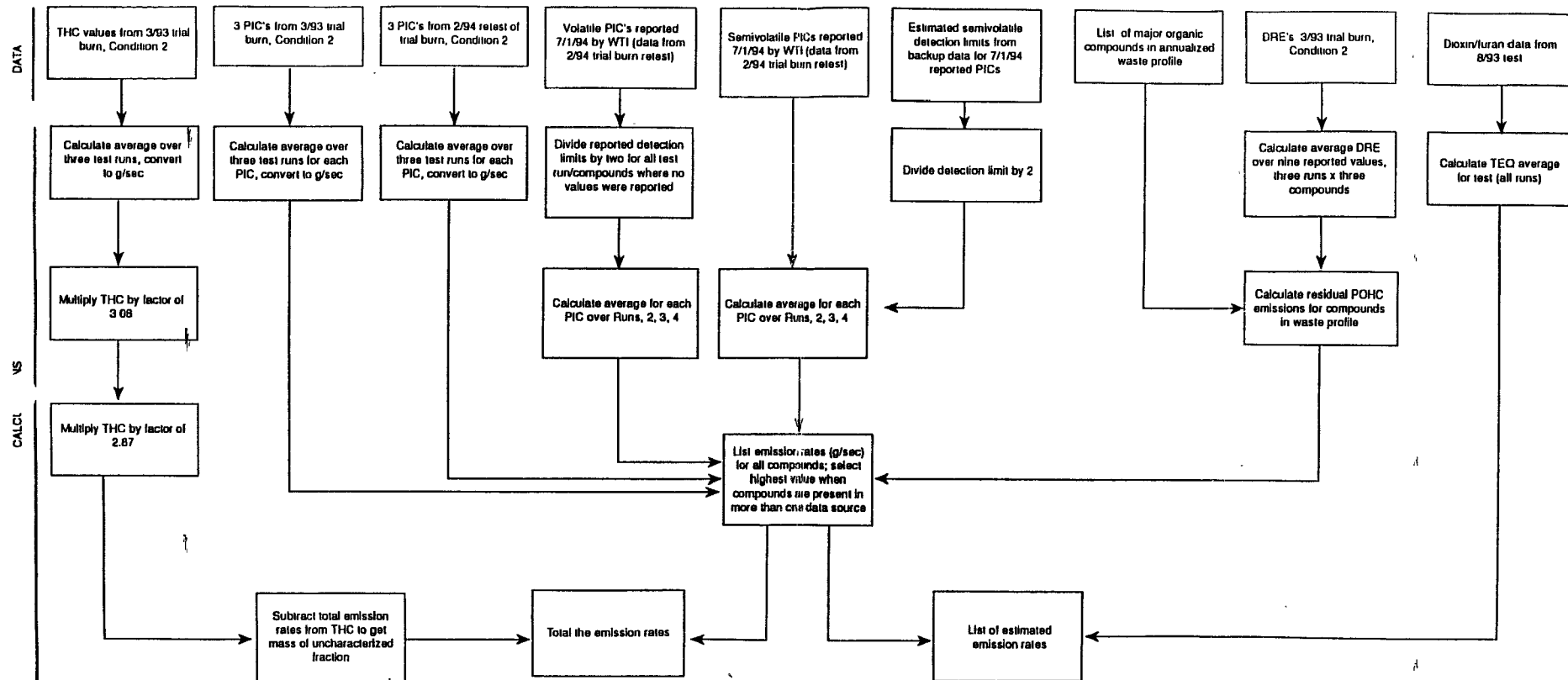
Figure IV-2. Procedures for estimating emissions of organic compounds.
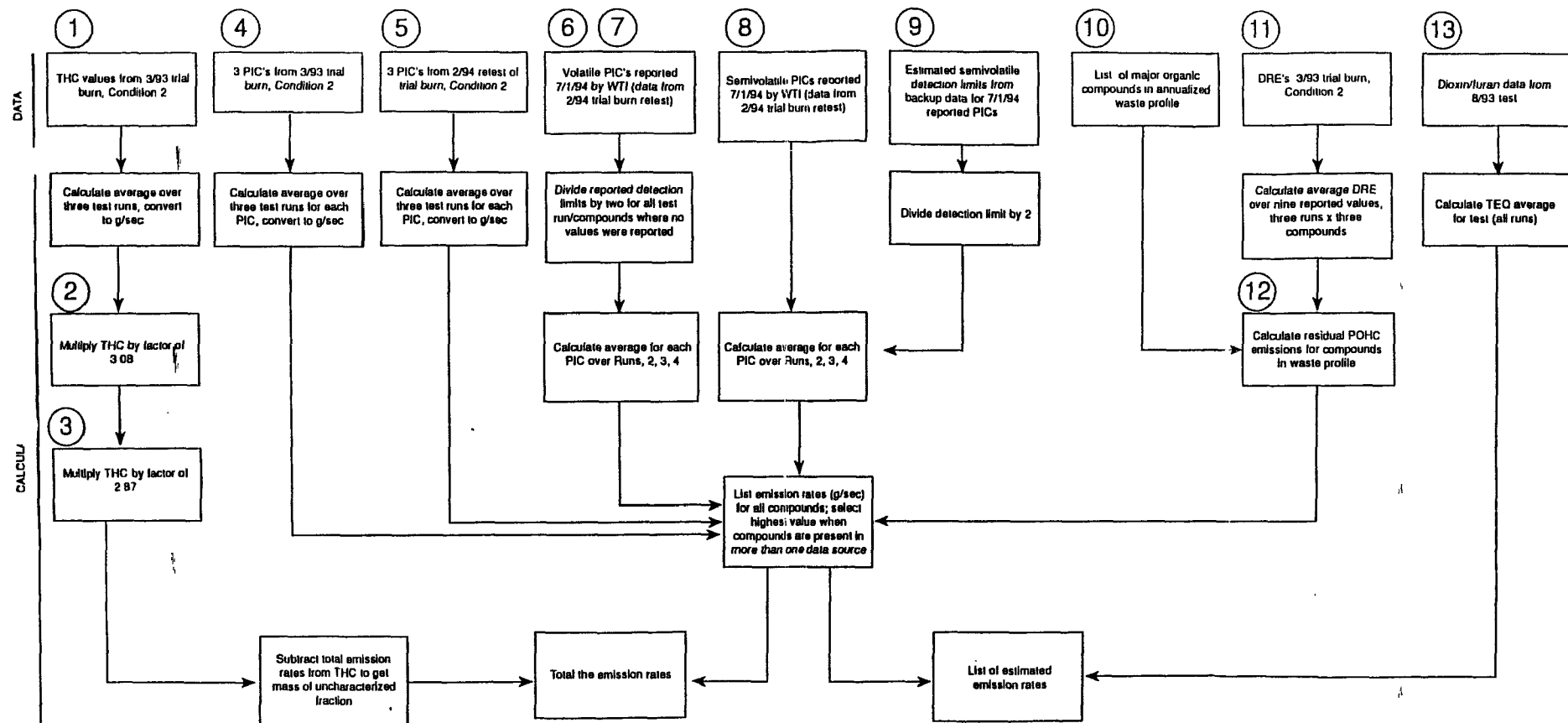
Figure IV-3. Procedures for estimating emissions of organic comppounds (estimation steps with uncertainties highlighted

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WORKING DRAFT 3 - NOT FOR RELEASE
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CHAPTER V. ESTIMATION OF EMISSIONS FROM OTHER SOURCES

A.   Evaluation of Emissions from Automatic Waste Feed Cutoffs

1.   Concerns to be Addressed

One of the critical factors affecting health impacts is the assessment of emissions during abnormal operation and accidents, including transients due to non-steady state operation, system upsets that could result in a waste feed cutoff, fugitive emissions due to leaks and spills, and catastrophic accidents such as fires and natural disasters. The Peer Review Panel recommended an alternative approach be developed to address these scenarios, if necessary.

2.   Approach

The approach for the analysis of emissions from automatic waste feed cutoffs (AWFCOs) is a two step process. The first step is to develop an estimated number of AWFCOs per year for the WTI facility. To the extent possible, the estimate of occurrences is based on the facility reports of AWFCOs and general non-compliance, as supplied by U.S. EPA Region 5. This step includes an examination of facility information to identify any trends in the occurrence rate or types of cutoffs which might have an impact on emissions to the atmosphere.

This initial step also includes a review of available AWFCO data from other operating incinerator facilities to determine if any of the data could be applied to develop the WTI-specific estimate.

Once an estimate of AWFCO frequency is developed, the second proposed step is to develop an estimate of the chemical composition of the emissions. Although established estimation techniques or studies dealing directly with nonroutine emissions from AWFCOs could not be identified, several sources of data are tentatively identified to develop this estimate.

These potential sources were evaluated for their usefulness and are briefly described below:

- A primary source of information is the February 1994 trial burn results. According to U.S. EPA Region 5 personnel, during Run 1 of this test, an AWFCO occurred, due to an exceedance of the minimum temperature setpoint. The results of this run are included in the trial burn, and are compared with three "normal" runs performed as part of the same condition.

- Another source of information involves the waste stream reported by the facility to be in the combustion chamber when the waste feed cutoff occurred. This information might be used to draw conclusions about unburned constituents in the fugitive release.

- An experimental study was performed at the Incineration Research Facility (IRF) in Jefferson, Arkansas. The purpose of this study was to simulate and quantify emissions from an incinerator operating under "upset" conditions, much the same way an incinerator might be operating prior to or during a cutoff. This research report was, in part, never finalized because some of the analytical equipment broke down during the experimental testing, and resources were not available to repeat the testing at a later date. Specifically, the total hydrocarbon (THC) analyzer broke down, and the experiments were completed without the benefit of that equipment or the resulting THC emission data. Although the research concluded that emissions do not significantly increase during an AWFCO, some have questioned whether this conclusion can be supported without the availability of THC emission data (Whitworth 1992). Because of these questions, the results or conclusion of this research have not been used here.

- In 1988, the Midwest Research Institute (MRI) conducted a study at a local incinerator. In part, the purpose of this study was to assess the relationship between CO and HC during upset conditions in the incinerator. It was thought that this test could yield some information about organic emissions during upset conditions.

- In the late 1980s, MRI was involved in a study commonly referred to as the "TME", or total mass emissions study. Although one of the objectives of this study was to determine the effect of upset conditions on mass emissions from an incinerator, this study in general did not show a great difference in emissions, probably because the facility

could not be forced into enough of an upset condition to yield usable data (U.S. EPA 1987).

In addition to gathering the data for the initial research, additional information was sought by contacting several people considered to be experts in the combustion emissions field. Those contacted are as follows:

Larry Waterland, Acurex Corporation: Mr. Waterland is responsible for the operation of the IRF, under contract to U.S. EPA. He was also responsible for the previously described test at the IRF, and has many years of experience in the field of combustion research. Mr. Waterland was unaware of any other studies or data relating to quantifying emissions from AWFCOs.

Dr. Paul Lemieux and Dr. William P. Linak, EPA RTP: Both Dr. Lemieux and Dr. Linak are considered to be experts in the field of combustion research. They provided a series of published articles on research conducted based on a 250,000 Btu rotary kiln simulator. This information is evaluated in this study and is discussed below.

The above-described approach provides an estimate of the number of AWFCO events per year at WTI and to quantify emissions during an AWFCO. A detailed discussion of the process is described below followed by a summary of conclusions and a discussion of uncertainties inherent in the analysis.

3. Frequency/Emissions Estimate for AWFCOs

a. Estimated AWFCO Frequency

As identified previously, the first step in this analysis is to develop an estimate of the annual number of AWFCOs at the WTI facility (WTI 1994). To develop this estimate Table V-1 summarizes a log of AWFCO events submitted by the WTI facility to Ohio and U.S. EPA. A more complete summary on all AWFCO events is presented in Attachment 5. As shown in Table V-1, 396 separate AWFCO events occurred, for varying reasons, over a span of approximately 9 months. Extrapolating from the occurrence of 396 AWFCOs over a period of 9 months, an annual frequency is estimated at 528 AWFCOs per year (396 X 12/9 = 528). Of the 396 reported AWFCOs, 108 are reported to have been associated with overpressure releases from the kiln. Extrapolating as in the previous case, it is assumed that 144 of the total

number of AWFCOs at the facility would cause a kiln overpressure which could result in a release through the kiln seals.

The information in Attachment 5 is analyzed further to determine if any trends could be discerned which might bear an impact on emissions. However, it is apparent that no single parameter consistently caused the events. A variety of failed equipment or unforeseen circumstances are identified as the cause of the AWFCOs. Furthermore, no data are available that could lead to conclusions about the type of wastes present in the kiln during each of the AWFCOs. Of the 108 reported positive pressure events, 56 are reported by the facility to have been the result of feed or waste flow problems. This converts to approximately 74 per year.

To verify the estimated annual AWFCO frequency of 528, or 44 per month, these estimates are compared with a report prepared by a joint EPA/OSHA Task Force established to evaluate worker health and safety compliance at 29 hazardous waste incinerators nationwide. The report provides the number of AWFCOs for a 30 day period for each of the 29 inspected facilities, ranging from no AWFCOs to >13,000 for a facility with 4 incinerators. Of the 29 units, 5 had no AWFCOs during the 30 day period and information was not available for 6. Of the remaining 18 units, 13 had greater than 44 AWFCOs per month. Even though the value of >13,000 AWFCOs per month seems anomalously high, the broad range of this study without consideration of the potential anomaly indicates that the use of facility-specific data provides the most accurate AWFCO estimate. Therefore, data from other operating facilities is not incorporated in the effort to estimate the WTI AWFCO emissions.

b.   Effect of AWFCOs on Emissions

For purposes of this evaluation, AWFCO events are broken into two major categories; AWFCOs associated with kiln overpressures, and all other types of AWFCOs. Each category of AWFCOs are analyzed to determine their potential impact to emissions. AWFCOs associated with kiln overpressures have been treated separately because these events can in some cases cause an uncontrolled "fugitive" release via puffing at the rotary kiln seals or other points.

The effect of other types of AWFCOs on emissions is less certain. Most other types of AWFCOs tend to have more potential impact on stack emissions (such as the potential for a low temperature AWFCO to result in higher organic emissions in the stack or the potential for a high temperature AWFCO to result in higher metals emissions in the stack) as opposed to the fugitive emission concerns associated with kiln overpressure events. Fugitive emissions from kiln seals, since they are uncontrolled and are not moderated by the air pollution control system, are seen as having a greater potential to result in significant emissions. The results of this initial analysis are presented below.

(1)   Non-overpressure AWFCOs

In an attempt to identify and quantify the effect of AWFCOs on the incinerator stack emissions, data generated during the Condition 2 retest performed at WTI are evaluated. Combustion experts with U.S. EPA's Air and Energy Engineering Research Laboratory, the contractor for U.S. EPA's Incineration Research Facility at Jefferson, Arkansas, and internal combustion experts at Midwest Research Institute (a consultant to U.S. EPA on this project) were also contacted during the preliminary research phase. Unfortunately, no published data, estimation techniques or studies were identified that directly address nonroutine emissions from AWFCOs. One experimental study designed to simulate and quantify emissions from an incinerator operating under upset conditions was identified. This study was performed at the IRF; however, the results were not conclusive (Whitworth and Waterland 1992).

In the absence of direct data establishing a link between AWFCOs and stack emissions, several other sources of potentially useful test results are identified. A primary source of information which provides actual data on the WTI incinerator performance during an non-overpressure AWFCO is the Condition 2 retest performed at WTI in February 1994. According to U.S. EPA Region 5 personnel, an AWFCO occurred approximately ten minutes before the end of Run 1 of the test, due to exceedances of the CO and minimum temperature setpoints caused by plugging in the high BTU waste feed lance. The plugging caused observable flow disturbances and increasing CO

readings (i.e., process upset) for the final hour of the four-hour sampling event. This AWFCO is included in the tabulation of total AWFCOs in Table V-1. Runs 2 through 4 occurred without mishap. The test results for Run 1 are therefore compared with the other runs to determine whether the AWFCO which occurred in Run 1 caused an identifiable increase in emissions. Table V-2 provides a comparison of destruction and removal efficiency (DRE) achieved during the four runs. The DRE standard was met for all four runs, and no significant differences in DRE were evident between Run 1 and the rest of the runs. In addition, dioxin emissions were not significantly higher in Run 1 than in Runs 2-4 (WTI 1993). Note, however, that testing stopped after the cutoff occurred and test results reflect an averaging throughout the sampling period. Nevertheless, no apparent difference is noted. The highest HC value recorded during the test is 0.10 ppm and the HC monitor continued to operate during the AWFCO. Insufficient data on PICS are available from this test to draw any conclusions about specific compounds. All other standards tested for were achieved. Based on the above information, there is no evidence that the AWFCO that occurred in Run 1 affected the performance of the incinerator in achieving the emission standards.

One other test study with potentially useful results was identified. This study was conducted at a rotary kiln incinerator (U.S. EPA 1987). It's purpose was to qualitatively and quantitatively study the characteristics of incinerator effluents under both steady state and transient upset operating conditions. In this study, transient CO spikes exceeding 700 ppm were induced by tripling the organic waste feed rate for a period of 7 seconds every 30 minutes. Emissions were measured while feeding waste containing 10% carbon tetrachloride, both for steady state operation and for operation with the transient CO spikes. A large number of volatile and semivolatile compounds were sampled and analyzed. Increases in emissions were measured for methane, methylene chloride (by a factor of approximately 47) and benzene (by a factor of approximately 15). However, the final concentrations during the transient conditions were still within the range normally seen from hazardous waste incinerators. No semivolatile compounds showed

significant increases in emissions. The conclusion drawn from this study is that no increase in emission concentrations were observed for most compounds as a result of operating the incinerator under transient upset conditions.

It is important to note that this study did not include AWFCOs, the use of which might be more conservative since the AWFCO limits the upset condition by stopping waste feeds. When coupled with the results of the February 1994 WTI test, it is apparent that the effect of nonover-pressure AWFCOs on incinerator emissions at WTI has not been quantifiable in the past. Although there are not a lot of data available, the effect does not appear to be significant and results in emission concentrations which are within "normal" range of incinerator emissions.

(2)   Overpressure AWFCOs

AWFCOs associated with kiln overpressures are of particular importance due to the possibility of escape of unburned or partially burned organics from the kiln seals. As previously noted, 108 AWFCO events in the 9 month reporting period were associated with kiln overpressures. However, 44 of the 108 events were associated with chunks of solidified ash, or clinker, falling into the slag quench tank, which is located directly beneath the secondary combustion chamber. This results in a sudden release of steam backing into the secondary combustion chamber, causing an overpressure event. An overpressure event of this nature is less likely to cause a release of waste constituents than an event associated with a feed or waste flow anomaly, since a steam related overpressure is most likely to release steam to the atmosphere. Therefore, 64 (or 85, on an annualized basis) of the 108 overpressure events have the potential to release unburned or partially burned organics from the kiln seals.

Little information is available on the duration of these events, or if these overpressure events were associated with an observable release from the kiln seals. However, two events are reported to have been observed as visible releases from the kiln seals (Victorine 1994). These two events are estimated to have resulted in emissions from the

kiln seals of three second and three minute durations, respectively. These durations are observer estimates, since no mechanism is in place to record the duration or magnitude of an event.

Although insufficient information exists to determine accurately an average duration for a puff event, certain general assumptions can be made. A major cause of kiln overpressure is the intermittent charging of containerized high BTU solid and liquid wastes in a batch mode. Once charged, the containers rapidly release volatile components into the gas phase. This rapid volatilization and subsequent combustion can cause temperature and pressure excursions in the kiln, resulting in kiln overpressure and "puffing." Assuming a sufficient excursion to exceed permit limitations for temperature, CO, or particularly kiln pressure, an AWFCO will occur, stopping all hazardous waste feeds to the kiln. Assuming that the excursion was also severe enough to cause external puffing to occur at the seals, this puffing will occur only for that period of time that the kiln remains under positive pressure. Once the system with the organic vapor released by the existing charge in the kiln, the kiln will return to negative pressure and the release will stop. Unless a significant failure such as loss of electrical power to the system has occurred, this equilibration process takes only a few seconds. Therefore, the assumption can be made that in many cases puffing releases will be limited to a few seconds in duration.

With respect to the cause of the AWFCO which resulted in the reported three minute release, the quench system pump failed, causing the backup quench pump to activate. However, a problem with the backup quench pump check valve caused the computer to interpret a quench system failure and shut down the induced draft (ID) fan. This failsafe is designed to protect the downstream APC equipment from being exposed to hot combustion gases. The operators were unable to override the computer system and restart the ID fan. Since the ID fan could not be quickly restarted, the event was, in essence, a significant failure as previously described. This event reportedly caused WTI to initiate changes to prevent the occurrence of this type of software problem in the future.

No estimation techniques or empirical studies quantifying emissions from overpressure releases have been identified in the scientific research. However, a series of research studies have been performed by the U.S. EPA Air and Energy Research Laboratory on various aspects of transient emissions from rotary kiln incinerators using a rotary kiln incinerator simulator. This 250,000 BTU/hr pilot-scale device simulated the operational features of full sized units in terms of volumetric heat release, gas-phase residence time and temperature profile. This series of studies was designed to evaluate incinerator performance under upset conditions. Specific research included the effects of parameters such as type and quantity of wastes fed, kiln temperature, and kiln rotational speed on the occurrence of transient puffs within the rotary kiln (Linak, et al. 1988, Wendt, et al. 1988, and Lemieux et al. 1990). The term "puff" in this application is used to denote the rapid release of volatile waste components into the gas phase, and does not necessarily mean that the gas phase components are released to the environment. Additional research evaluated the means of minimizing transient puffs by controlling waste container packaging and operating a rotary kiln at low rotational speed and low temperature (Lemieux et al. 1992).

Building on these previous research studies, the most recent research study (Lemieux et al. 1993) addressed emergency stack vent (ESV) issues related to rotary kiln incinerator using the rotary kiln simulator. This research examined optimum settings of kiln operating parameters to minimize PIC emissions during a simulated ESV opening event. A series of 12 tests were performed, varying kiln air flow rates and rotational speeds. A surrogate performance indicator was developed to evaluate performance of the simulator based on CO, THC and soot generation rates weighted as a factor of stoichiometric oxygen requirements. This surrogate indicator represented a measure of the relative degree of poor combustion occurring in the unit, and alleviated the need for costly, time consuming sampling and analyzing of individual compounds. However, a limited number of compounds were tested using tedlar gas bag samples. Gas bag sampling was performed for one run which was a baseline "puff" test and one run performed

under the simulated ESV opening conditions. The concentrations of VOCs from these two tests were of the same order of magnitude, leading to the conclusion that the concentration of organic PICs emitted during an ESV opening appear comparable to those emitted from the rotary kiln prior to secondary combustion during normal batch operation.

Concentrations of the 19 organic compounds analyzed during the two runs described above ranged from non-detectable to a high of 1100 - 1900 ng/L for methylene chloride. Toluene was present in concentrations from 100 - 830 ng/L, and most other compounds ranged from 10 - 100 ng/L, including benzene at 29 ng/L. While it is tempting to use these analytical results to attempt to draw conclusions about possible concentrations of compounds emitted during an overpressure release at an incinerator such as WTI, the authors of the study specifically cautioned against doing so, by stating the following:

> Measurements made on the rotary kiln incinerator simulator are not intended to be directly extrapolated to full-scale units. It is, for example, very difficult to scale up some of the important gas-phase mixing phenomena from the simulator, where, for instance, stratification is known to be significant (Cundy et al. 1989). The purpose of the simulator is to individually examine the fundamental phenomena that occur in full-scale units, and to gain an understanding of the qualitative trends that would be found in a full-scale rotary kiln. In no way should it be inferred that the concentrations of pollutants from this apparatus would be the same as those from full-scale units (Lemieux, et al. 1993).

Given the possible similarity in emissions from puffs and ESV openings, it is pertinent to examine the results of an analysis performed on ESV openings (Kroll et al. 1992). An unsteady-state computer model was developed to estimate combustion gas flow, temperature and

hydrocarbon concentration versus time for ESV events. The modeled incinerator was similar to the WTI unit in size and design, and was operated under similar conditions with respect to waste feed rate, temperatures and gas flow rates. The results of this hypothetical simulation indicated that assuming an initial hydrocarbon concentration represented by benzene (from waste) in the 700 ppm range in the system, the concentration of benzene at the ESV would drop to <100 ppm in under 2 minutes, and to near zero in 5 minutes. Note that these values are the result of a computer simulation, and a number of assumptions were made relative to the incineration system, ambient conditions, combustion chamber conditions and hydrocarbon vapor concentration. However, this analysis illustrates the expected rapid decrease in concentration of volatile constituents over the duration of a puff episode.

A simpler, hypothetical analysis is presented to illustrate the potential order of magnitude of emissions which could be expected as a result of a kiln overpressure episode. To conduct the hypothetical analysis, a waste constituent is first selected for the analysis. The constituent must be a common component of the waste and also volatile with known health effects to be illustrative. Based on waste profile data, benzene is selected for this analysis. Based on information on individual waste streams provided in the WTI waste profile data base, the maximum concentration of benzene which could be expected to be present in any waste stream, either liquid or solid, is 10%. Only one of the 74 waste streams in the data base has a higher potential concentration of benzene, at 0% to 25%, and this waste stream comprises less than 2% of the total annual projected volume fed to the incinerator. Conversely, a number of waste streams list a potential maximum benzene content of 9% or 10%, so 10% is selected for this hypothetical illustration.

To further the illustration, it is assumed that the incinerator waste feed is a combined maximum of 8000 lb/hr liquids and solids, and that a drum weighing 500 lbs is charged, causing a pressure excursion and AWFCO, and subsequently, an overpressure release. From this scenario, several assumptions are made about the

concentration of benzene in the kiln and the relative contributions from the various waste streams. Under normal operating conditions in a rotary kiln incinerator, pumpable wastes are atomized and rapidly dispersed in the gas stream. During an AWFCO event, all feeds are immediately cut off and the liquid waste present in the kiln prior to cut-off is destroyed in a matter of seconds. Bulk solid wastes have a much longer residence time in the kiln after the AWFCO occurs. The resulting difference in residence time is illustrated below by calculating relative concentrations at the time the drum is charged. The relative contribution of benzene from each stream is as follows:

Liquids and bulk solids:
$$(8000 - 500)\text{lb/hr} * (0.1) /3600 \text{ sec/hr} = 0.21 \text{ lb/sec};$$
and

Drum:
$$500 \text{ lb} * (0.1) = 50 \text{ lb, instantaneously charged.}$$

Compared to the instantaneous 50 lb contribution from the drum, the 0.21 lb/sec contribution from the liquids and bulk solids (over several seconds maximum time) is not significant. At the point of AWFCO initiation, the liquid and bulk solids feeds will cease, leaving the drum as the remaining contributor of benzene to the kiln.

Next, it is assumed that the benzene volatilizes and is perfectly mixed within the kiln chamber, and that 50% is destroyed in the kiln. This value, which can not be accurately measured, is selected as a conservative estimate since engineering judgment would indicate actual destruction efficiency would be expected to be much higher. To estimate the potential amount of benzene which could be released in this hypothetical case, calculations are based on the assumption that the vapor generated by the drum release is equal to the amount of gas released from the kiln through the seals. Assuming a kiln operating temperature of 1800°F, the benzene volume in the incinerator is calculated as follows:

$$\frac{50 \; lb \; * \; (1-0.50)}{78 \; lb/mole} \; * \; 379ft^3/mole \; * \; \frac{(1800^\circ F \; + \; 460^\circ F)}{520^\circ F} \; = \; 528 \; ft^3 \; benzene \; vapor$$

Based on an internal volume of 7,600 ft³ for the incinerator, this volume of benzene would represent, and therefore displace 7% of the kiln's volume. If 7% of the kiln's contents escapes as part of the overpressure release, the following amount of benzene will be released:

$$(50 \; lb)(0.50)(0.07) \; = \; 1.75 \; lb \; benzene \; emitted$$

At an estimated 85 AWFCOs per year potentially causing overpressure releases, a maximum of 149 lb of benzene would be released. In a real world setting, this release would be composed of a number of different unburned and partially burned organics. Benzene is selected to represent the range of compounds emitted.

This hypothetical illustration is not intended to present a means of calculating emissions from this type of release, but to provide a sense of the order of magnitude of emissions that might occur as a result of an overpressure release. Most of the assumptions in this illustration are made to create a sufficiently simple system to allow the emission calculation to be performed. Estimating emissions for the range of compounds that could be expected to be present is beyond the scope of this illustration.

4. Uncertainty

The uncertainty inherent in estimating releases associated with AWFCOs is too great to allow the estimation of emissions from these events. These uncertainties include the following:

• Lack of any empirical or theoretical data showing whether or not a release occurs as a result of a non-overpressure AWFCO;

- Lack of empirical data or a suitable estimation method to quantify releases from overpressure AWFCOs. Specific uncertainties in this case include type and degree of destruction of wastes present in the kiln at the moment the AWFCO occurs, and duration (quantity) of release (vs. duration of AWFCO event);

- Calculations performed in this section illustrate that any such potential emissions appear to be very small when compared to overall potential fugitive emissions from this facility. Because of the small fraction of overall risk attributed to fugitives, and because of the small fraction of fugitives attributed to kiln seals, the impact of potential kiln seal emissions is deemed negligible; and

- lack of information necessary to determine the exact level of positive kiln pressure necessary to overcome the seals and cause a significant leak, or the percentage of overpressure events which actually result in a leak.

A summary of the key assumptions used in this analysis are listed in Table V-8.

5.   Conclusions

Based on the analysis described above, the following conclusions can be reached.

- The projected annual frequency for AWFCOs at WTI is 528, with a projection of 85 of those events involving overpressure releases with the potential to release unburned or partially burned waste constituents from the kiln seals.

- Increased emissions associated with AWFCOs not related to kiln overpressures are probably not significant.

- AWFCOs associated with kiln overpressures do have the potential for emissions via overpressure releases. These releases may be similar to organic emissions from an ESV opening. No direct method of estimating emissions from these events is identified, although the magnitude of these events is expected to be relatively small when compared to the total fugitive emissions

identified in this risk assessment (See Table V-7, page V-39). This order of magnitude is incorporated by the use of conservative assumptions in estimating routine emissions. Although this release does not occur at stack height, resulting in a potentially different dispersion factor, the release would be at a far higher temperature ($\sim 1800°F$), resulting in a much faster plume rise.

B. Estimation of Fugitive Emissions from Routine Operations

1. Introduction

This section describes the estimation of organic emissions from a variety of routine, non-incinerator activities at the WTI site. The term fugitive is used, because emissions from most of these activities are not directly associated with a stack. The activities include routine waste handling in tanks and containers, and fugitive emissions associated with drips and leaks from pumps, flanges, seals and valves. Originally, this section was to cover estimation of emissions from accidental spills, however, this portion of the analysis evolved into an Accident Analysis presented in Volume VII of the Risk Assessment. However, information relating to routine spills and storage accidents is retained in this section for informational purposes.

2. Site Description

Various activities at the facility are examined to identify operations most likely to lead to releases of fugitive emissions and to determine a reasonable approach to estimating releases due to routine operation. Physical operations at WTI include transport of waste onto the site, transferring, mixing, and blending (WTI 1982).

Reportedly, WTI normally handles on average, approximately one dozen trucks of incoming waste per day and does not normally receive more of one type of truck than another (e.g., tank trucks of bulk liquids versus semitrailers of drums). Therefore, it is assumed that half of the trucks (6) are tankers. Bulk liquid wastes are pumped out the bottom of the truck. No railcar shipments are currently possible, but WTI has reportedly been considering installation of railcar unloading facilities.

Trucks entering the facility are sent to the truck holding area on the west end of the facility so that truck contents can be identified. Liquid organic wastes are pumped from tanker trucks into a waste reception tank in the organic waste tank farm, located on the southeast section of the facility. Sludges are unloaded into sludge reception tanks. Liquid materials which arrive in containers are pumped into

the three container pump-out tanks located outside the drum processing building. Reception tanks allow for waste decanting and settling of suspended solids. Lighter fractions are pumped to appropriate holding tanks. Sludges, slurries or highly viscous material (which have settled to the bottom of reception tanks) are pumped to sludge holding tanks.

Holding tanks are used for accumulating working inventories of pumpable waste to be fed to the incineration system. Holding tanks are used in the following number: two for accumulation of waste sludges, two for accumulation of aqueous waste, six for accumulation of all other waste liquids. Waste sludges can be pumped to either the blending tanks or directly to the incineration system.

Blending tanks are used to combine and mix compatible pumpable wastes into a uniform mixture to maximize the consistency and stability of the combustion process. Each of the three blending tanks is equipped with an agitator. In some cases, recirculation loops are used in lieu of agitators. The waste mixture in the blending tanks is pumped to lances in the front wall of the incineration system.

Organic storage tanks described in the part B permit application (WTI, 1982) consist of carbon steel, stainless steel, lined carbon steel or stainless steel, and fiberglass reinforced plastic. Reception tanks have a 7,000 gallon capacity, holding tanks have a 20,000 gallon capacity, and blending tanks have either a 10,000 gallon or 20,000 gallon capacity.

3. Review of Releases at TSDFs

Historical reports of releases at WTI and at other TSD facilities provide perspective as to the operations at the WTI site and the possibilities for routine release of emissions. A summary of a historical review is presented below.

a. Incidents at WTI

First, an analysis of all the non-incinerator related incidents reported from November 1993 through May 1994 at the WTI facility is reviewed to identify operations or to see if the incidents are linked to specific accidents (Victorine 1994). A total of eleven incidents were reported. Eight are categorized as tank-related incidents, two are categorized as drum sampling or repackaging incidents, and one is reported as a spill. On-site release volumes from drum sampling/repackaging and simple spills ranged from negligible fumes to 10 gallons of waste.

Of the eight reported tank-related incidents, three are the result of tank overfilling, two are the result of improper maintenance, one is the result of an accident to the tank. A failed check valve and incompatibility of waste with tank material accounts for the remaining two tank-related incidents. For incidents where volumes are reported, on-site releases as a result of these incidents range from 8 to 18 gallons.

On-site releases as a result of non-tank related incidents which did not involve incinerator operation (i.e., during "routine operations") range from fumes liberated during repackaging to 10 gallons. Table V-3 provides a breakdown of the tank related incidents reported from November 1993 through May 1994 at the WTI facility. Non-tank related spills at WTI range from vapors released during repackaging to 10 gallons.

Based on the above information, a wide range of spill volumes could be expected as a result of releases that could occur at the WTI facility. Based on the reported spill quantities and the lack of any information showing that any of these spills were highly volatile, it is assumed that minor routine spills are relatively small sources of emissions (i.e., compared to overall fugitive organic emissions) at this plant and hence are negligible for the purposes of this risk assessment. Instead, spills are evaluated in the Accident Analysis included as Volume VII of the Risk Assessment.

b.   Incidents at Other Facilities

A look at a profile on reported incidents from Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs) (Mangino 1992) shows, in general, that a majority of non-incinerator related incidents are due to tank releases which also account for the largest reported spill volumes. Of the 15 identified non-incinerator related incidents at TSDFs, 12 are tank related. For incidents where volumes are reported, release volumes range from 40 to 20,000 gallons. Of the 12 tank related incidents, 7 are related to tank transfers, 1 occurred during blending, 2 are attributed to arson, 1 is attributed to tank rupture, and no reason is given for the final reported tank release. The remaining three non-incinerator incidents are related to repackaging for incineration (2) and equipment failure. Volumes of releases from these incidents ranged from 55 to 75 gallons. The EPA study concluded that the major causes of releases from tank systems are unrelated to the characteristics

of the material stored in the tanks, assuming that the stored material is compatible with the material of construction of the tank system. Therefore, it is likely that hazardous material storage tanks do not have significantly different rates of failure (rupture/explosion) regardless of what kind of material is stored.

A significant cause of releases (not counting operator errors) from above ground tank systems is found by U.S. EPA to be from ancillary equipment failures (including failures of pumps, flanges, couplings, interconnecting hoses, and valves).

Since incinerator explosions documented at other facilities in the past have tended to be either steam explosions (such as a waste heat boiler exploding, or a large slag ball falling into a quench tank) or explosions of small quantities of energetic waste, no significant amounts of hazardous constituents were believed to have been released to the atmosphere during these events. For this reason incinerator explosions are not evaluated in this assignment.

Reported releases at TSDFs, in general, are evaluated in order to determine typical causes associated with releases and typical volumes released. These parameters are summarized in Table V-4. As shown in Table V-4, spill volumes as a result of tank failures range from 40 gallons to an estimated 20,000 gallons at TSDFs. The majority of these incidents involved releases between 2,000 gallons and 6,000 gallons with a mean spill volume of approximately 5,500 gallons. The largest spill identified is 638,000 gallons, and resulted from a railcar spill (Mangino 1992).

4.   Identification of WTI Sources of Releases

Based on the information provided above, and evaluation of the processes at the WTI site, the following routine waste handling sources are selected for evaluation of fugitive releases.

a.   Organic Waste Tank Farm

The organic waste tank farm is enclosed in a building located on the southeast section of the facility. The tank farm houses the blending, holding, and reception tanks. All tanks are vented to the incinerator when operating, and to a carbon adsorption bed when the incinerator is not operating.

b.   Fugitive Emissions

For the purposes of this risk assessment, fugitive emissions include emissions associated with drips, leaks, and vapor releases from equipment transporting the waste. This equipment includes pumps that move the waste through pipes between the tanks and to the incinerator, as well as seals and flanges in the piping. Although WTI has a program in place to detect and repair leaking equipment of this type, some emissions may still occur. The bulk of this equipment is located within the organic tank farm building, and releases from this building are to the atmosphere through building vents, rather than to the incinerator or carbon adsorption bed.

c.   Container Processing

Drums which contain liquids are pumped into the container pumpout tanks located outside the drum processing building. The pumpout tanks are vented to the incinerator when operating, and to a carbon adsorption bed when the incinerator is not operating.

d.   Open Waste Water Tank

This tank is also referred to as the "C" water tank. It is open to the atmosphere and is used to collect stormwater runoff from areas of the facility that are expected to contribute small amounts of contamination to the runoff. However, there is some potential that the collected runoff could contain small amounts of contamination.

e.   Truck Wash

The truck wash is a building enclosed on two sides and open to the atmosphere on the ends to allow trucks to drive through. The facility management reports that the truck wash has rarely been used.

5.   Emission Estimation Calculations

a.   Organic Waste Tank Farm and Pump Out Tanks

For purposes of estimating emissions, all tank calculations are grouped together. This includes the blending, holding, pumpout, and reception tanks. Throughput values for emission calculations are based on the waste profile

data base. The total base facility throughput (pumpable and non-pumpable) is 29,880,000 lb/yr, or 15,000 TPY. Based on facility estimates, the total expected throughput for the facility at full operation is 70,000 TPY. Therefore, throughputs used in various calculations have been scaled up by a factor of 4.67 (70,000/15,000).

Uncontrolled emissions from all these waste tanks (not the waste water tank) are calculated using U.S. EPA's Storage Tank Emission Calculation Software, Version 2.0, November, 1993. A multicomponent waste stream mixture is created based on the top 12 constituents (by weight) found in the pumpable waste stream of the MRI waste profile data base. These 12 components are prorated to form a simplified base input stream for the Tanks program. However, these compounds are not very toxic or volatile. Hence, additional compounds are selected based on toxicity, volatility and quantity predicted in waste stream and added to the program at their un-prorated values, to provide the most realistic emission estimates possible for these selected compounds. Because the toxicity of a given compound may be different for human receptors than ecological receptors, two iterations of the tanks program are performed using two lists of selected compounds. The first listed selected compounds relating to human risk and the second listed selected compounds relating to the ecological-risk assessment. These compounds are listed in Table V-5 and V-6 respectively. In this way, estimated risks are adequately evaluated for each assessment. Please refer to Volume V (Human Health Risk Assessment).

Attachment 6 contains an example printout from the tanks program. This printout shows all assumptions and default values used in the program itself.

b.   Fugitive Emissions from Equipment Leaks

Fugitive emissions are calculated by summing the emissions of all components below.

Emission Factors (lb/yr)
Pump Seal   0.047
Valve (In-Line)   0.00051
Release   0.23

Example calculation for pump seal leakage:

$$n * \frac{0.047 \text{ lb}}{\text{hour}} \times \frac{24 \text{ hr}}{\text{day}} * \frac{250 \text{ day}}{\text{year}}$$

Where n = the number of pumps in the process.

Assumptions used to Calculate Fugitive Emissions

- From drawing on page 16-25 of WTI Part B Permit application (WTI 1982), there are 37 major pumps. Assumed eight would be working at any given time.

- Average emission factors for heavy liquids will apply to the sources.

- Eight lines would be running at any given time with 4 valves per line (32).

- One pressure relief valve would be in operation at any given time.

- Operations of processing 24 hr/day for 250 day/yr.

c. · **Container Processing**

Assumptions used to Calculate Emissions from Containers

- 55 gallon drums will be representative of the majority of packaged waste received (i.e., range from 1 qt to 85 gal sizes).

- Random sampling will be performed on 10% of all drums.

- Repackaging will be done on 35% of drums.

- Emissions are equivalent to releases from a leaky valve with heavy liquids.

- Facility receives 6 truckloads per day for 250 days per year.

- Approximately 30 drums per truckload are processed for 8 hr/day.

- Average fugitive emission factors for the Synthetic Organic Chemical Manufacturing Industry (SOCMI) are used. These factors take into account a leak frequency determined from field studies in the SOCMI. Light liquids have a vapor pressure greater than 0.1 psia @ 100°F.

- Processing averages 15 min (0.25 hr) to repackage drum (Repackage 35% + Sample 10% = 45%)

d.   Open Waste Water Tank

Emissions from the open top stormwater runoff tank are calculated using the mass transfer correlations and emissions equations provided in AP-42 for waste water treatment systems. For purposes of these calculations, the tank is treated as a non-aerated sump of the same dimensions. The recommended default values for average wind speed and temperature are used, and the design average throughput of 15,000 gal/day from the WTI permit application is also used. Although the emissions are reported as VOCs, the calculations are performed using toluene as the constituent at an average concentration of 10 ppm. Toluene is selected because it ranks among the top ten constituents by weight in the composite pumpable waste stream from the waste profile data base, and it's value for diffusivity is in the midrange of the top ten constituents for the pumpable waste stream.

Individual liquid and gas phase mass transfer coefficients

k_ℓ (m/s) = $1.0 \times 10^{-6} + 144 \times 10^{-4} (U^*)^{2.2} (Sc_L)^{-0.5}$; $U^* < 0.3$

k_ℓ (m/s) = $1.0 \times 10^{-6} + 34.1 \times 10^{-4} U^* (Sc_L)^{-0.5}$; $U^* > 0.3$

For $U_{10} > 3.25$ m/s and F/d < 14

where:

$$U^* \ (m/s) = (0.01)(U_{10})(6.1 + 0.63(U_{10}))^{0.5}$$

$$Sc_L = \mu L/(\rho LDw)$$

$$F/D = 2 \ (A/\pi)^{0.5}$$

$$K_\ell = \text{liquid phase mass transfer coefficient}$$

$$k_g \ (m/s) = (4.82 \times 10^{-3})(U_{10})^{0.78} \ (Sc_G)^{-0.67} \ (d_e)^{-0.11}$$

where:

$$Sc_G = \mu_a/(\rho a D_a)$$

$$d_e(m) = 2(A/\pi)^{0.5}$$

$$k_g = \text{gas phase mass transfer coefficient}$$

Overall mass transfer coefficients

$$K = (k_\ell \ Keq \ k_g + k_\ell)$$

where:

$$Keq = (H/(RT)$$

Air emissions

$$N(g/s) = K \ C_L \ A$$

where:

$$C_L(g/m^3) = Q \ Co/(KA + Q)$$

Parameters and Constants

-U_{10} = 4.47 m/s   Wind speed at 10 m above the
                              liquid surface

-$D_w \rightarrow 8.6 \times 10^{-6}$ cm 2/5   Diffusivity of constitutent in water
(selected toluene as midrange)

$-\mu_L = 8.93 \times 10^{-3}$ g/cm   Viscosity of water

$-\rho_L = 1$ g/cm^3 Density of water

$d_e = 33$ ft $= 10.1$ m   Effective diameter

$\mu_a = 1.81 \times 10^{-4}$ 3/cm-s   Viscosity of air

$\rho_a = 1.2 \times 10^{-3}$ 3/cm^3 Density of air

$D_a = 0.87$ cm 3/5 for toluene   Diffusivity of constituent in air

$H = 0.00668$ atm m^3/gmol   Henry's Law Constant of constituent

$R = 8.21 \times 10^{-5}$ atm m^3/gmol °F   Universal gas constant

$T = 298$ K (25°C)   Temperature of water

$A = 80.1$ m^2 Waste water surface area

$C_o = 10$ ppm or 100 ppm   Initial concentration of constituent in the liquid phase

$Q = 15,000$ gal/day   Volumetric flow rate

$Q = 6.57 \times 10^{-4}$ m^3/s

e.   **Truck Wash**

Emissions from Truck Washing are calculated using the emission factors below:

Emission Factors (lb/hr);
Valve (light) = 0.016; and
Valve (heavy) = 0.00051.

An example calculation from truck washing is as shown:

$$\frac{1 \text{ hr}}{\text{truck}} \times n \text{ trucks} \times \frac{250 \text{ day}}{\text{year}} \times 0.60 \times \frac{0.016 \text{ lb}}{\text{hour}}$$

Where n = number of trucks carrying volatile liquids.

- Assumptions Used to Calculate Emissions from Truck Washing:
- 60% of trucks entering facility contain washable wastes (i.e., all tankers + 10% of all container bearing trucks which may have hauled leaky containers);
- One-third of these trucks contain light liquids;
- One-third of these trucks contain heavy liquids;
- One-third of these trucks contain non-volatile solids with negligible emissions;
- All washing is done under a hooded work station. Emissions from truck washing are equivalent to emissions from one leaky valve;
- Clean out time is one hour per truck; and
- Normally handles 12 trucks/day.

6. Compound Specific Emissions

Uncontrolled fugitive vapor emissions from tanks in the tank farm building are calculated using U.S. EPA's Storage Tank Emission Calculation Software (TANKS2), Version 2.0, November 1993. The program uses physical/chemical properties of the waste stream constituents, such as molecular weight, vapor pressure, and concentration, in deriving emission rates. Although the actual waste streams stored in the tanks at WTI may change over time, a representative, multicomponent waste stream was used in the TANKS2 program to represent the top 12 constituents[1] (by weight) projected to be found in the pumpable waste stream received by WTI based on facility waste profile sheets.

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[1] The top 12 constituents by weight are estimated to comprise 60 percent of the total pumpable waste stream, and include octane (used to represent unidentified hydrocarbons), cresol, methanol, methyl ethyl ketone, toluene, cyclohexanone, ethyl acetate, 1-butanol, xylenes, methyl isobutyl ketone.

In the HHRA (Volume V) and SERA (Volume VI), additional surrogate chemicals are selected to represent the volatility and toxicity of fugitive vapor emissions from the WTI facility. Because the endpoints differ in these two assessment (i.e., human and ecological populations, respectively), the surrogate chemicals also differ. Table V-5 and V-6 reflect compounds of concern and the estimated, compound-specific emission rates for the HHRA and SERA respectively.

The total estimated fugitive vapor emissions from the tanks in the tank farm building were estimated to be 212 pounds per year, as shown in Table V-7. Fugitive vapor emissions from the individual types of tanks contained within the tank farm building are also indicated in Table V-7, as well as the total estimated emissions from the other sources of vapor emissions (e.g., open waste water tank, container processing, truck wash and fugitive emissions). Techniques are not available to predict compound specific emissions rates from the other sources of vapor emissions. Therefore, the results of the tank farm/CAB modeling are extrapolated to the other three fugitive organic vapor emission sources by assuming that the chemical composition of fugitive emissions (expressed as a weight fraction) will be the same for all of the identified fugitive emission sources. Thus, weight fractions of individual constituents (ECOCs) derived from the above analysis of tank farm emissions are multiplied individually by the total estimated fugitive emission rates (all chemicals) for each of the sources of fugitive organic emissions. In this fashion, compound specific emission rates are estimated for each source of fugitive vapor emissions.

Controlled emissions are estimated based on the following. As stated in the permit application and verified by U.S. EPA, emissions from all tanks and the container processing facility are vented to the incinerator when operating, and to a carbon adsorption system when the incinerator is not operating. Data on the number of hours of incinerator operation are derived from reports from WTI to the Ohio EPA regarding waste feed cutoff occurrences. These data show that the incinerator operated approximately 53% of the time over a period from December 1993 through July 1994. Therefore, it is assumed that the control efficiency for 53% of the emissions from the above operations is 99.99%. For the other 47% of emissions routed to the carbon adsorption system, a control efficiency of 90% is assumed based on average efficiency data contained in the Evaporative Loss Section of the Compilation of Air Pollution Emission Factors, AP-42 (U.S. EPA 199

3a). Although the figure of 47% is considered to be on the high side, this conservative value is used in part to account for the observation that at those times when the incinerator is operating at less than full capacity, a small fraction of the flow from the vapor recovery system may be directed to the CAB system to ensure sufficient negative pressure in the vapor recovery system.

7.   Uncertainty

Following are the major sources of uncertainty associated with estimation of fugitive emissions from routine storage activities.

- The amount of wastes handled by the facility on an annual basis (low uncertainty factor).

- Number and type (bulk vs. containers) of truckloads of waste received by the facility (low uncertainty factor).

- Because the pumpable waste stream from the waste profile data base is used to calculate emissions, all uncertainties described in Section II.5 associated with the waste profile data base are inherent to these calculations (high uncertainty factor).

- The tank emissions calculation software is based on empirical equations using default values for parameters like seasonal temperature, default windspeed, and meteorological data. Also, since the actual waste handling pattern between tanks is unknown, it is assumed that the entire volume of pumpable wastes passed through each type of tank once, rather than all tanks sequentially (medium uncertainty).

- The relative percent of time the tank and container pumpout emissions are vented to the incinerator vs. the carbon adsorption bed could vary from the 53% to 47% ratio (low uncertainty).

- Uncertainty relative to the waste water tank includes the throughput of stormwater, type and concentration of contaminants in the water (both are dependant on rainfall and spills or leakage of waste), and uncertainties

associated with the empirical equations used to calculate the emissions (low uncertainty).

- For container releases and truck washing, uncertainty is based on number of containers or vehicles processed, type of waste contained, and use of relatively non-specific, generic emission factors to calculate emissions (medium uncertainty).

- For fugitive emissions, uncertainty is associated with accurate counting of the number of pumps, flanges, valves and seals based on plan drawings contained in the permit application, and the use of relatively non-specific emission factors to calculate emissions (medium uncertainty).

It is believed that there is not any general trend in these uncertainties which would result in an overall underestimation of fugitive emissions, and conservative assumptions are generally made throughout this risk assessment. These assumptions are summarized in Table V-8.

C.   Emissions from Ash Handling

1.   Concerns to be Addressed

There was concern over potential exposure to fugitive emissions of incinerator ash. These fugitive emissions could be caused by routine handling of residues from the combustion of hazardous waste at the WTI facility. This section provides the details of the procedures used to estimate the potential magnitude of fugitive ash.

2.   Approach

The purpose of this section is to characterize emissions from ash handling activities at the WTI facility. The ESP ash handling activities are of primary concern.

Fugitive emissions from ash handling are estimated by applying a series of emission factors which were developed based on empirical test data generated at a pulverized coal-fired power plant employing an ESP for particulate matter control. Factors were available for complex airborne particle size distribution and were based on tests of flyash loadout from the ESP (Muleski et al. 1986).

Although these factors were developed based on flyash from the combustion of coal, fugitive emissions are dependent more on the physical form of the flyash than on the feed (or waste) stream being combusted. Specific information on the characteristics of the WTI ash will be incorporated into the estimation of emissions (See Volume V). The necessary information includes texture of the ash, moisture content, production rate, and a physical description of the ash handling process, including the control device(s) producing the ash.

3. Estimation of Emissions

This section provides an estimate of particulate matter emissions from the slag and ash handling activities at the WTI site, and a description of the technique used to calculate the particulate matter emission rate.

a. WTI Ash Handling System

In order to evaluate WTI's ash handling system, a diagram of the ash handling process, based on information provided in WTI's RCRA Part B Permit application, is provided as Figure V-1. Each step in the ash handling process is then identified based on the potential for ash to be emitted to the environment. Those processes which are uncovered, vent to the environment or could potentially leak are identified in the diagram with an "F".

In general, two separate groups of ash handling activities are identified. These include bottom ash loadout from the secondary chamber and fly ash loadout from the air pollution control equipment. Stack emissions of particulate matter have been previously characterized, and have not been included in this estimation.

Each of the groups of ash handling activities is evaluated in detail to determine the potential for fugitive emissions. The ash from the secondary chamber falls into a quench tank, where the ash will be thoroughly wetted due to the submerged feed chute design within the quench tank. The ash is then transferred via wet conveyor to portable drop boxes which are on trucks. After each box is filled it is closed and hauled by a licensed independent hauler to a disposal facility. Since the ash is wet and double sealed in the trucks, no fugitive emissions are expected to occur either in the form of airborne emissions from the ash or fluid leakout which could dry and be

tracked out by truck traffic. Therefore, emissions from this source are estimated to be negligible.

Ash handling activities associated with the ESP flyash are a potential source of fugitive emissions. These activities include transfer of the ash into covered trucks vented to a baghouse. The ash is transferred through a series of hoppers, drag chains and a bucket elevator. Note that the drag chains and bucket elevator are not marked as sources of fugitive emissions on Figure V-1. Testing and evaluation of fugitive emissions at facilities that employ these types of devices has shown that these devices are not a source of fugitive emissions, if properly maintained. In addition, transfer of fly ash into covered trucks is not considered a source of fugitive emissions, since dust-laden air displaced by the ash in the trucks is vented back into the baghouse. Therefore, emissions are estimated only for the bag filter.

b. Description of Estimation Technique

Particle emissions associated with flyash loading and unloading are estimated using an empirical emission factor based on a field testing program conducted at a coal fired power plant equipped with an ESP (Muleski and Pendleton 1986). This study was conducted in part to characterize the emissions of particulate matter from the loading of flyash into trucks. Although the combustion of coal and hazardous wastes are dissimilar activities, flyash generated from similar control devices is expected to behave similarly under the same conditions, with respect to fugitive emissions. In general, particle behavior is dependent more on the physical form of the flyash than on the feed (or waste) stream being combusted.

The emission factor determined during the empirical study is adjusted to reflect the fact that the flyash was wetted prior to loading, with an average moisture content of 29%, whereas the WTI flyash is not wetted, and is assumed to have a negligible moisture content. The average factor determined during the study is 0.107 lb/ton flyash, and the recommended adjustment, based on scientific judgement, is a factor of 2 to 10 (10 being conservatively high). For information purposes, both factors are used in the following calculations to provide a range of expected emission rates.

c.   **Emission Estimate**

The following assumptions are used in calculating fugitive emission rates:

- The flyash generation rate from the ESP is assumed to be 5,300 T/Y. This value is based on both the original estimation of flyash generation rate provided in the Part B permit application, and the total ash content of the "generic" waste streams created from the waste profile (Chapter II). Both values are found to be approximately the same. Since a major portion of ash fed to the combustor is converted to bottom ash, it is likely that this value is a conservatively high estimate of the actual flyash generation rate.

- The control efficiency for the fabric filter controlling emissions from the silo is assumed to be 99.5%, based on AP42 factors for typical collection efficiencies of particulate matter control devices, for the particle size range of 2.5 to 10 um.

The emission calculation then becomes:

low range: (5300 T/Y)(0.107 lb/T)(2) = 1,134 lb/yr, uncontrolled

high range: (5300 T/Y)(0.107 lb/T)(10) = 5,671 lb/yr, uncontrolled

Taking into account the fabric filter:

low range: (1,187 lb/yr)(1-0.995) = 5.7 lb/yr

high range: (5,671 lb/yr)(1-0.995) = 28.4 lb/yr

d.   **Conclusion**

Based on the above calculations, a conservative estimate of fugitive particulate matter emissions from the WTI facility is 28 lb/yr.

4. Uncertainty

The primary uncertainties associated with this calculation are the flyash generation rate and the conversion from wetted flyash to dry flyash. Key assumptions used are highlighted in Table V-8. However, this uncertainty is expected to be low, within the stated range of emissions.

Table V-1

POSITIVE PRESSURE AND TOTAL AUTOMATED WASTE FEED CUT-OFFS (AWFCOs) REPORTED BY MONTH AT WTI

Description	Date									
	11/93	12/93	1/94	2/94	3/94	4/94	5/94	6/94	7/94	Totals
Feed/Flow Positive Pressure AWFCOs	8	1	5	8	3	9	17	5	-	56
Other Positive Pressure AWFCOs	3	1	-	-	-	-	3	1	-	8
Clinker/Quench Positive Pressure AWFCOs	-	-	2	1	1	10	14	10	6	44
Total Positive Pressure AWFCOs	11	2	7	9	4	19	34	16	6	108
Total AWFCOs Per Month	59	35	30	26	33	73	85	24	31	396

Source: Waste Technologies Industries, Report of AWFCO Incidences to Ohio EPA, 1994. All positive pressure AWFCOs identified by facility.

Table V-2. DRE RESULTS FROM THE 1994 TRIAL BURN CONDITION NO. 2

	Run 1	Run 2	Run 3	Run 4
CCl$_4$	99.9972%	99.9943%	99.9964%	99.9972%
MCB	99.9998%	99.9997%	99.9997%	99.9994%
TCE	99.9997%	99.9996%	99.9995%	99.9995%

Source: 1994 Trial Burn Report

Table V-3. SUMMARY PROVIDED BY PERMITTEE OF EQUIPMENT/PROCEDURAL FAILURE (UNRELATED TO INCINERATOR) WHICH RESULTED IN SPILLS OR RELEASES

Matrix Released	Volume Released	Material	Cause	Description
liquid	10 gal	hi-BTU waste	unknown	not given
liquid	not given	aqueous	transfer	Tank overflow during transfer
liquid	not given	aqueous	transfer	Tank overflow during transfer
liquid	not given	aqueous	tank failure	Failed check valve on tank
liquid	not given	quench water	accident	Slag fell into quench tank, caused it to leak
liquid	8 gal	acid/solvent sludge	accident	Rupture disk blown due to overfilling
liquid	5 gal	waste	improper maintenance	Disconnected hoses which were under pressure
liquid	18 gal	hazardous waste	improper maintenance	Failure to reconnect a vent line on a sludge pump after servicing
air	not given	unknown	misidentified or unstable waste	Tank lining failure due to incompatibility of tank with waste
air	not given	cumene hydroperoxide	misidentified or unstable waste	Three 5-gallon pails liberate odors during repackaging
air	not given	hazardous waste	misidentified or unstable waste	Six drums were opened for sampling and started smoking

Source: Draft Memorandum from G. Victorine, US EPA Region V to WTI project file. Compilation of Reports on Downwash, Procedural/Equipment Failures, and Test Results, May 19, 1994.

Table V-4. SUMMARY OF RELEASES AT TSDFs[1]

Size Class	Matrix Released	Volume Released	Released From	Material	Cause	Description
Small	Liquid	40 gal	Tank	Unknown	2	Spilled while filling a tank
	Liquid	75 gal	Pipe	Cool water	5	Recycle cooling water system ruptured
	Liquid	55 gal	Drum	Characteristic waste	6	Mixed several incompatible wastes
	Solid	55 gal*	Drum	Organic peroxide	6	Explosion and spilled drum during consolidation of materials
Large	Liq/Air	200 gal	Tank	Acid	6	Failure to identify corrosives as reactive caused tank boil over and plume of chlorinated gas
	Liquid	300 gal	Tank	Unknown	2	Spilled while filling tank
	Liquid	9,600 gal	Hose	Solvent & Wastewater Contaminated waters	2	Hose detached from pump during transfer
	Liquid	30,000 gal	Hose	Acetone	2	Hose broke during transfer and pump continued for a short time Vapors ignited while the operator was checking tanker level.
	Liquid	4,000 gal*	Tank Truck	Unknown	2	Three other tank trucks also caught fire Spilled during a railcar transfer
	Liquid	638,000 gal	Railcar	Maleic anhydride	2	Spilled from storage tank—no reason given
	Liquid	6,000 gal	Tank	Toluene	3	Large spill occurred when a tank ruptured
	Liquid	20,000 gal	Tank	Solvents	3	Pipe connecting blend tank to incinerator corroded through
	Liquid	3,000 gal	Tank	Hydrochloric acid	5	Arson, 2 employees arrested
	Liquid	2,000 gal	Tank	Ammonia	11	Arson, 2 employees arrested
	Liquid	2,200 gal	Tank		11	

* Assumed volume.

Key to Cause:

1 Unknown	2 Transfer
3 Tank failure	4 Improper maintenance
5 Equipment failure	6 Misidentified/unstable waste
7 Inclement weather	8 Equipment design
9 Operating conditions	10 Utility failure
11 Arson	

[1] Memorandum from M. Mangino, USEPA Region V to A. Anderson. *Summary of Incidents at Incinerators and Commercial TSDFs.* Preliminary draft profile on reported incidents, March 1982 through October 1992 (Mangino 1992)

Table V-5. EMISSIONS FROM ORGANIC WASTE STORAGE TANKS (HUMAN HEALTH - CONSTITUENTS OF CONCERN)

Compound	Emissions (lb/yr)					Emissions by Compound (g/sec)
	Blending Tanks	Holding Tanks	Pump Out Tanks	Reception Tanks	Total by Compound	
Octane	6.13	6.13	5.09	5.34	22.68	3.26E-04
Cresol	0.020	0.020	0.017	0.018	0.075	1.08E-06
Methanol	10.11	10.11	8.40	8.81	37.42	5.38E-04
MEK	8.97	8.97	7.45	7.82	33.22	4.78E-04
Toluene	3.04	3.04	2.53	2.65	11.26	1.62E-04
Acetone	20.38	20.38	16.93	17.77	75.46	1.09E-03
Cyclohexanone	0.31	0.31	0.26	0.27	1.14	1.64E-05
Ethyl Acrylate	2.73	2.73	2.27	2.38	10.10	1.45E-04
Butanol	0.28	0.28	0.23	0.24	1.025	1.47E-05
Xylene	0.68	0.68	0.56	0.59	2.51	3.60E-05
MIBK	1.04	1.04	0.86	0.91	3.85	5.54E-05
2-Nitropropane	0.397	0.397	0.330	0.346	1.47	2.11E-05
Acrylonitrile	0.48	0.48	0.40	0.42	1.78	2.57E-05
Carbon Disulfide	1.44	1.44	1.20	1.26	5.33	7.67E-05
Carbon tetrachloride	0.97	0.97	0.80	0.84	3.58	5.15E-05
Dibromoethane	0.0475	0.0475	0.0395	0.0414	0.176	2.53E-06
Dichloroethylene	1.41	1.41	1.17	1.23	5.23	7.53E-05
Formaldehyde	11.99	11.99	9.96	10.45	44.38	6.38E-04
Hydrazine	0.0306	0.0306	0.03	0.027	0.113	1.63E-06
Pyridine	0.50	0.50	0.42	0.43	1.862	2.68E-05
Total by Tank Type (lb/yr)	70.94	70.94	58.94	61.84	262.7	
Total by Tank Type (g/sec)	1.02E-03	1.02E-03	8.48E-04	8.89E-04	3.78E-03	

Table V-6. EMISSIONS FROM ORGANIC WASTE STORAGE (ECOLOGICAL)

Compound	Emissions (lb/yr)					Emissions by Compound (g/sec)
	Blending Tanks	Holding Tanks	Pump Out Tanks	Reception Tanks	Total by Compound	
Octane	6.17	6.17	5.13	5.38	22.85	3.29E-04
Cresol	0.021	0.021	0.017	0.018	0.076	1.10E-06
Methanol	10.2	10.2	8.46	8.88	37.7	5.54E-04
MEK	9.04	9.04	7.52	7.89	33.5	4.82E-04
Toluene	3.06	3.06	2.55	2.67	11.3	1.63E-04
Acetone	20.5	20.5	17.1	17.9	76.0	1.09E-03
Cyclohexanone	0.31	0.31	0.58	0.27	1.15	1.65E-05
Ethyl Acrylate	2.74	2.74	2.28	2.39	10.2	1.46E-04
Butanol	0.279	0.279	0.232	0.243	1.03	1.48E-05
Xylene	0.37	0.37	0.307	0.322	1.37	1.96E-05
MIBK	1.05	1.05	0.869	0.911	3.87	5.57E-05
Chloroform	1.41	1.41	1.17	1.23	5.22	7.51E-05
Benzene	1.31	1.31	1.09	1.14	4.84	6.96E-05
Formaldehyde	11.97	11.97	9.96	10.45	44.35	6.38E-04
Dimethylamine	5.32	5.32	4.43	4.64	19.71	2.83E-04
Hydrazine	0.031	0.031	0.025	0.027	0.113	1.63E-06
Acetonitrile	0.566	0.566	0.471	0.494	2.10	3.01E-05
Carbon disulfide	1.44	1.44	1.20	1.26	5.33	7.67E-05
Dimethylhydrazine	0.404	0.404	0.336	0.352	1.50	2.15E-05
Total by Tank Type (lb/yr)	76.59	76.59	63.70	66.82	283.7	
Total by Tank Type (g/sec)	1.10E-03	1.10E-03	9.16E-04	9.61E-04	4.08E-03	

Table V-7. SUMMARY OF ESTIMATED EMISSIONS FROM ROUTINE OPERATIONS

Source	Estimated Emissions (lb/yr)	Estimated Emissions (g/sec)
Reception tanks	50.1[1]	7.2x10-4
Pumpout tanks	47.7[1]	6.8x10-4
Holding tanks	57.2[1]	8.2x10-4
Blending tanks	57.2[1]	8.2x10-4
Open wastewater tank	202	2.9x10-3
Container processing	12.1	1.7x10-4
Truck wash	9.9	1.4x10-4
Fugitive emissions[2]	2,126	3.1x10-2
TOTAL	2,562	3.69x10-2

[1]   These estimates are calculated based on control by venting to the incinerator or carbon absorption.

[2]   These emissions include flanges, seals, pumps, valves, etc.

TABLE V-8
Key Assumptions for Chapter V

Assumption	Basis	Magnitude of Effect	Direction of Effect
Many kiln overpressure events causing AWFCO's result in puffing releases that are limited to a few seconds in duration	Container charging of high BTU waste can cause rapid release of gaseous volatiles, resulting in kiln positive pressure. Kiln returns to equilibrium and negative pressure within a few seconds, ending release	low	underestimate
Calculations can be performed to illustrate the potential order of magnitude of release from kiln seals during overpressure release	Professional judgement based on specific kiln parameters and waste feed characteristics	low	unknown
All fugitive chemicals of potential concern have been identified and included, even though the list is limited to pumpable wastes (e.g., nonpumpable waste may also be a source of fugitive emissions)	Non-pumpable wastes are handled separately from pumpable wastes and because they are generally not volatile, they are not likely to result in fugitive emissions	low	underestimate
The composite liquid waste stream list is truncated to include only the chemicals in the top 90% by mass	Simplifying assumption to focus assessment	low	underestimate
All fugitive emission sources have been identified	A site inspection was conducted to identify all significant sources of fugitive emissions.	low	underestimate
Six tanker trucks of bulk liquids are received per day	Best available data	low	unknown
The 12 monthly flyash samples used to determine the fugitive chemicals of concern and amounts are representative of actual conditions. Because organic compounds were not detected in these samples, they are not considered. Additionally, the chemicals on the analyte list includes all the chemicals that are likely to be present.	Best available data	low	underestimate
The same chemical composition is used for all fugitive sources	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
Tank emissions calculated based on simplified 12 component waste stream with selected additional toxic/volatile components	Simplifying assumption to adapt to software constraints	low	variable*

TABLE V-8
Key Assumptions for Chapter V

Assumption	Basis	Magnitude of Effect	Direction of Effect
A series of simplifying assumptions were made to allow calculation of emissions from container processing, truck wash, and leaks from pumps/flanges/seals	Simplifying assumptions based on site information and available empirical estimation techniques	low	variable*
Emission calculations for open wastewater tank were based on toluene	Simplifying assumption based on empirical estimation technique	low	variable*
Controlled emission estimates for tanks are based on venting to incinerator 53% of time and CAB 47% of time	Based on incinerator on-line data for first year of operation	low	overestimate
The contributions to the CAB system are based on the estimated number of drums received at the facility, the number of drums sampled and repackaged, and the container processing rate	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
Emissions from the CAB system are estimated as equivalent to releases from a leaky valve with heavy liquids using appropriate emission factors	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
The wastewater tank is treated as a non-aerated sump using a default wind speed and an average throughput. Toluene is used as a surrogate for VOC behavior.	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
Emissions from the truck wash are equal to releases of heavy and light liquids from valves	Professional judgment based on a review of information on facility design and operation, and predicted waste characteristics.	low	unknown
The emissions factor for flyash from coal burning is applied to incinerator flyash emissions but increased by a factor of 10 because of negligible moisture content	Professional judgment based on relationship between water content and erodibility.	low	unknown

Figure V-1. Slag and ash handling diagram—WTI facility.

CHAPTER VI. REFERENCES

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ATTACHMENT 1

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

GENERATOR INFORMATION

. Generator Name:_____ _____

Generator Address _____

Generator USEPA ID·_____

Generator Contact/Phone:_____

BILLING INFORMATION

.. Billing Name ____

Billing Address:_____

Customer Service Contact/Phone:_____

SHIPPING INFORMATION

.. PACKAGING: Bulk Solid ___ Bulk Liquid _X_ Drum Liquid _X_ Drum Solid _X_
(Check as many as
  appropriate.)   Drum Liquid/Solid Mixture _X_ Other Container ___

Type of container per U.S.EPA manifest instructions:CF DF DM DW TC TP TT _____

.. ANTICIPATED ANNUAL VOLUME (pounds/year):___330,000.00

.. HMIS Code: HEALTH_2*_ FLAMMABLE_3__ REACTIVE_0__ PPE_K6_

.. SPECIAL HANDLING INFORMATION

        SARANEX SUIT _____

None ____

Is this a dust hazard? Yes ___ No _X_

SAMPLING INFORMATION

7. A. Was this sampled by the Generator? Yes ___ No _X_ If no, answer B and C.

B. Sample Source:N/A_____

C. Date Sampled:_____

Sampler's Name/Company:_____

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

PROPERTIES AND COMPOSITION

8. Process Generating Waste: <u>OPERATION</u>   _____
                                                                              _____

9. Waste Name: <u>.   </u>
               <u>   </u>

10. Identify ALL USEPA listed and characteristic waste code numbers(D,F,K,P,U):
    <u>D001, D002, D004, D005, D006, D007, D008, D009, D010, D011, D018</u>
    <u>D019, D021, D022, D023, D024, D025, D026, D027, D028, D029, D030</u>
    <u>D035, D036, D038, D039, D040, F001, F002, F003, F004, F005</u>
    To list additional USEPA waste code numbers, use additional pages and check here.___

11. Physical State @70F:
    A. Solid ___ Liquid ___ Sludge ___ Solid and Liquid Mixture ___
    B. If liquid, are there multilayers? Yes _X_ No ___ N/A ___
    C. Free Liquid Range <u>0</u> to <u>20</u> %
    D. If there is a liquid or sludge present, is this waste pumpable? Yes ___ No _X_
       a. If no, can this waste be heated to improve flow? Yes ___ No _X_
       b. If yes, will the solids pass through a 1/8-inch screen? Yes ___ No ___

12. A. pH: ≤2.0 ___ >2.0 to <12.5 ___ ≥12.5 ___ Not Applicable ___
    B. Strong Odor Yes ___ No ___ Describe _____

13. A. Liquid Flash Point: <73°F ___ ≥73°F ___ ≥100°F ___ ≥140°F ___ ≥200°F ___ N/A ___
    B. Boiling Point: <100°F ___ ≥100°F _X_

14. PCBs ___ If yes, concentration_____ppm, Pyrophoric ___ Explosive ___
    Radioactive ___ Shock Sensitive ___ Oxidizer ___ Carcinogen _X_ Infectious ___
    Asbestos ___ Dioxins ___ Gas ___ Bromoform >500 ppm _X_
    Dichlorodifluoromethane >500 ppm _X_ Trichlorofluoromethane >500 ppm _X_ None ___

15. Benzene Yes _X_ No ___
    If yes, a) Concentration <u><100,000</u> ppm or mg/l
            b) Does the waste contain water in an amount greater than or equal to 10%? Yes ___ No ___
            c) Is this waste stream subject to the control requirements of 40 CFR 61.340 to 61.358?
               Yes ___ No ___

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

16. CHEMICAL COMPOSITION: List ALL constituents (using specific chemical names) present in any concentration and forward available analysis. TOTAL COMPOSITION MUST EQUAL OR EXCEED 100%.

Does your waste contain Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Lead, Mercury, Silver or Thallium? Yes ___ No _X_

If yes, include the metals that your waste contains in the constituent list below and specify a representative concentration range for each metal.

Constituents	Range	Units	
PAINT RESIN,PIGMENTS,ADHESIVE S,POLYMERS,INK,OIL	10-100	Percent	
1,1 DICHLOROETHYLENE	0-1	Percent	
1,1,1 TRICHLOROETHANE	0-50	Percent	
1,1,2 TRICHLORO 1,2,2 TRIFL UOROETHANE	0-50	Percent	
1,1,2 TRICHLOROETHANE	0-50	Percent	
1,2 DICHLOROETHANE	0-1	Percent	
1,4 DICHLOROBENZENE	0-1	Percent	
2,4 DINITROTOLUENE	0-1	Percent	
2-ETHOXYETHANOL	0-50	Percent	
2-NITROPROPANE	0-50	Percent	
ACETIC ACID	5-25	Percent	
ACETONE	0-50	Percent	
ARSENIC	0-1	Percent	
BARIUM	0-1	Percent	
BENZENE	0-9	Percent	
BROMOFORM	0-500	ppm	
CADMIUM	0-1	Percent	
CARBON DISULFIDE	0-50	Percent	**
CARBON TETRACHLORIDE	0-50	Percent	
CHLORINATED FLUOROCARBONS	0-50	Percent	
CHLOROBENZENE	0-50	Percent	
CHLOROFORM	0-1	Percent	**
CHROMIUM	0-1	Percent	
CITRIC ACID	5-25	Percent	
CRESOLS	0-100	Percent	
CRESYLIC ACID	0-50	Percent	
CYCLOHEXANONE	0-50	Percent	
DICHLORODIFLUOROMETHANE	0-500	ppm	
ETHYL ACETATE	0-50	Percent	
ETHYL BENZENE	0-50	Percent	
ETHYL ETHER	0-50	Percent	
FORMIC ACID	5-25	Percent	

List additional constituents on following page, check here and attach. _X_

17. Mark all extremely hazardous substances ≥1% with **, or check the following: None ___

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Attachment 1

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

16. **CHEMICAL COMPOSITION:** List ALL constituents (using specific chemical names) present in any concentration and forward available analysis. TOTAL COMPOSITION MUST EQUAL OR EXCEED 100%.

Constituents	Range	Units	
ISOBUTANOL	0-50	Percent	
LEAD	0-1	Percent	
MEK	0-50	Percent	
MERCURY	0-259	ppm	
METHANOL	0-50	Percent	
MIBK	0-50	Percent	
N-BUTYL ALCOHOL	0-50	Percent	
NITROBENZENE	0-100	Percent	**
O-CRESOL	0-1	Percent	**
ORTHO DICHLOROBENZENE	0-50	Percent	
PHOSPHORIC ACID	5-25	Percent	
PYRIDINE	0-50	Percent	
SELENIUM	0-1	Percent	
SILVER	0-1	Percent	
SULFURIC ACID	5-25	Percent	**
TETRACHLOROETHYLENE	0-500	ppm	
TOLUENE	0-50	Percent	
TRICHLOROETHYLENE	0-50	Percent	
TRICHLOROFLUOROMETHANE	0-500	ppm	
WATER	0-40	Percent	
XYLENE	0-50	Percent	

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Attachment 1

External Release Draft
Do Not Cite or Quote

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

8. Check ONE: This Waste is a: Wastewater ____   Nonwastewater _X_

.9. If this waste is subject to any California list restrictions, enter the letter from below(either A or B from section 20) next to each restriction that is applicable:

HOCs ____   PCBs ____   Acid ____   Metals ____   Cyanides ____   None _X_

/ASTE IDENTIFICATION TABLE (not applicable ____)

20. Identify ALL Characteristic and Listed USEPA hazardous waste numbers that apply (as defined by 40 CFR 261). For each waste number, identify the subcategory (as applicable, check none, or write in description from 40 CFR 268.42, and 268.43).

Ref. No.	A. U.S. EPA Hazardous Waste Code(s)	B. Subcategory Enter the Subcategory Description - If Not Applicable, Simply Check None — Description	None	c. Applicable Treatment Standards Performance-Based: Check as Applicable 268.41(a)	268.43(a)	Specified Technology: If Applicable, Enter the 40 CFR 268.42 Table 1 Treatment Code(s) 268.42	D. How Must the Waste Be Managed? Enter the Letter From Below
1	D001	Ignitable Liq. 261.21(a)(1) Low TOC < 10% total organic carbon		No	No	INCIN	A
2	D001	Ignitable Liq. 261.21(a)(1),High TOC >or= 10% total org.carbon		No	No	INCIN	A
3	D002	Acid, Alkaline, and other based on 261.22		No	No	INCIN	A
4	D004		None	Yes	No		A
5	D005		None	Yes	No		A
6	D006		None	Yes	No		A
7	D007		None	Yes	No		A
8	D008		None	Yes	No		A
9	D009	Low Mercury; less than 260 mg/kg mercury		Yes	No		A
10	D010		None	Yes	No		A
11	D011		None	Yes	No		A

To list additional USEPA waste numbers and categories, use following page and check here: _X_

Indicate in Section 20D how the waste must be managed under the land disposal restrictions:

A. RESTRICTED WASTE REQUIRES TREATMENT
B. RESTRICTED WASTE TREATED TO PERFORMANCE STANDARDS
C. RESTRICTED WASTE SUBJECT TO A VARIANCE
D. NO APPLICABLE MANAGEMENT STANDARDS
E. EXEMPT UNDER 40 CFR 268.42

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Appendix III-1
Attachment 1

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

WASTE IDENTIFICATION TABLE (Continuation) (not applicable __)

20. Identify ALL Characteristic and Listed USEPA hazardous waste numbers that apply (as defined by 40 CFR 261). For each waste number, identify the subcategory (as applicable, check none, or write in description from 40 CFR 268.42, and 268.43).

Ref. No.	A. U.S. EPA Hazardous Waste Code(s)	B. Subcategory Enter the Subcategory Description - If Not Applicable, Simply Check None		c. Applicable Treatment Standards			D. How Must the Waste Be Managed? Enter the Letter From Below
		Description	None	Performance-Based: Check as Applicable 268.41(a)	268.43(a)	Specified Technology: If Applicable, Enter the 40 CFR 268.42 Table 1 Treatment Code(s) 268.42	
12	D018		None	No	No		NONE
13	D019		None	No	No		NONE
14	D021		None	No	No		NONE
15	D022		None	No	No		NONE
16	D023		None	No	No		NONE
17	D024		None	No	No		NONE
18	D025		None	No	No		NONE
19	D026		None	No	No		NONE
20	D027		None	No.	No		NONE
21	D028		None	No	No		NONE
22	D029		None	No	No		NONE
23	D030		None	No	No		NONE
24	D035		None	No	No		NONE
25	D036		None	No	No		NONE
26	D038		None	No	No		NONE

Indicate in Section 20D how the waste must be managed under the land disposal restrictions:

A. RESTRICTED WASTE REQUIRES TREATMENT
B. RESTRICTED WASTE TREATED TO PERFORMANCE STANDARDS
C. RESTRICTED WASTE SUBJECT TO A VARIANCE
D. NO APPLICABLE MANAGEMENT STANDARDS
E. EXEMPT UNDER 40 CFR 268.42

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Do Not Cite or Quote

WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

WASTE IDENTIFICATION TABLE (Continuation)(not applicable __)

20. Identify ALL Characteristic and Listed USEPA hazardous waste numbers that apply (as defined by 40 CFR 261). For each waste number, identify the subcategory (as applicable, check none, or write in description from 40 CFR 268.42, and 268.43).

Ref No.	A. U.S. EPA Hazardous Waste Code(s)	B. Subcategory Enter the Subcategory Description - If Not Applicable, Simply Check None		C. Applicable Treatment Standards			D. How Must the Waste Be Managed?
		Description	None	Performance-Based: Check as Applicable		Specified Technology If Applicable, Enter the 40 CFR 268.42 Table 1 Treatment Code(s)	Enter the Letter From Below
				268.41(a)	268.43(a)	268.42	
27	D039		None	No	No		NONE
28	D040		None	No	No		NONE
29	F001		None	No	Yes		A
30	F002		None	No	Yes		A
31	F003		None	No	Yes		A
32	F004		None	No	Yes		A
33	F005		None	No	Yes		A

list additional USEPA waste numbers and categories, use following page and check here:_____

Indicate in Section 20D how the waste must be managed under the land disposal restrictions:

    A. RESTRICTED WASTE REQUIRES TREATMENT
    B. RESTRICTED WASTE TREATED TO PERFORMANCE STANDARDS
    C. RESTRICTED WASTE SUBJECT TO A VARIANCE
    D. NO APPLICABLE MANAGEMENT STANDARDS
    E. EXEMPT UNDER 40 CFR 268.42

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WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

TRANSPORTATION

21. TRANSPORTATION AND HANDLING INFORMATION

    A. Is this a DOT Hazardous Material? Yes _X_ No ___
    B. Proper Shipping Name WASTE FLAMMABLE LIQUID, NOS _____
    C. Hazard Class or Division Explosive (1.4C) _____
       Package Group _____ I.D. _____
    D. Additional Description (MEK,XYLENE) _____
    E. CERCLA Reportable Quanity(RQ) and units(lb, kg)___ 1.00 Pounds
    F. Constituent or Waste Code RQ is based on _____

CERTIFICATION

22. GENERATOR OR DESIGNEE CERTIFICATION

I hereby certify that all information submitted in items 1, 4, 7, 8, 9, 10, 12a, 13, 14, 15 and 16 contains true and accurate descriptions of this waste. The signature on incoming Land Disposal Restriction Forms at the time of waste receipt will certify the information in items 18, 19 and 20. Any sample submitted is representative as defined in 40 CFR 261 - Appendix I or by using an equivalent method. All relevant information regarding known or suspected hazards in the possession of the generator has been disclosed. I authorize WTI to obtain a sample from any waste shipment for purposes of recertification. This information is the generator's best estimate and is not used as a limitation upon WTI's receipt of waste shipments or quantities in excess of these estimated amounts.

_____   _____
Signature   Date

_____   _____
Printed (or typed) name   Company

                                _____
                                         Title

Waste Analysis Decision

X Initial   ___ Renewal   Date:_____

Generator's Name: _____

WASTE PRODUCT REVIEW INFORMATION

1. Is incineration either the required treatment technology or the basis for any treatment standard for the identified waste codes(s)? Yes _X_ No ___

2. Is this waste profile a lab pack? Yes _'_ No _X_

3. Does WTI intend to normally use this waste as the high BTU feed for the incineration process? Yes ___ No _X_

4. Were supplemental analyses performed? Yes _X_ No ___
   If yes, supplemental analysis results are attached.

5. Name of testing laboratory if other than WTI _____

6. Are there any MSDS sheets attached? Yes ___ No _X_

APPROVAL SIGNATURES

_____   Date:____/____/____
Laboratory

_____   Date:____/____/____
Safety

_____   Date:____/____/____
Environmental

_____   Date:____/____/____
Operations

Regulatory Agency Use only; OEPA

___ Accepted   ___ Conditional Acceptance   ___ Acceptance Denied

___ Conditional acceptance upon Waste Management Alternatives Plan submission. Decision effective for six (6) months from this date. ___/___/___. _____ (OEPA initials)

___ Accepted, Waste Management Alternatives Plan approved. _____ (OEPA initials)

Conditions for acceptance or reasons for denial:

_____

_____

_____

Signature _____   Date ____/____/____

Title _____

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WASTE TECHNOLOGIES INDUSTRIES
WASTE PROFILE SHEET

23. WASTE ANALYSIS RESULTS. Is this a miscellaneous special waste? Yes ___ No ___

Identification	Measured Value	Possible Waste Codes	Total Constituent Analysis	TCLP
A. ANIONS				
BROMIDE, %	<0.04			
CHLORIDE, %	3.1			
FLUORIDE, %	<0.05			
IODINE, %	N/A			
SULFUR, %	.2			
SULFIDES, ppm	<20			
CYANIDES (Amenable), ppm	<20			
CYANIDES (Non-Amenable), ppm				

B. METALS

	Measured Value	Possible Waste Codes	CONCENTRATION SOLID Mg/Kg	LIQUID Mg/l
ANTIMONY, ppm	<25			
ARSENIC, ppm	<2.5	D004 ARSENIC	100	5.0
BERYLLIUM, ppm	<0.03			
BARIUM, ppm	6	D005 BARIUM	2,000	100
CADMIUM, ppm	<5	D006 CADMIUM	20	1.0
CALCIUM, ppm	2330			
CHROMIUM, ppm	170	D007 CHROMIUM	100	5.0
COPPER, ppm	8.9			
LEAD, ppm	740	D008 LEAD	100	5.0
LITHIUM, ppm	<5			
MERCURY, ppm	<0.5	D009 MERCURY	4	0.2
NICKEL, ppm	<10			
PHOSPHORUS, ppm	98			
POTASSIUM, ppm	<100			
SELENIUM, ppm	<2	D010 SELENIUM	20	1.0
SILVER, ppm	<5	D011 SILVER	100	5.0
SODIUM, ppm	31			
THALLIUM, ppm	<35			
ZINC, ppm	400			

C. PHYSICAL PROPERTIES

FLASHPOINT °F	78
BTU/lb	15800
WATER, %	<1
VISCOSITY, cp	<24
ASH, %	15
DENSITY, g/ml	.984
pH	9.4
SETTABLE SOLIDS, %	28
PCB(s), ppm	YES <50
FREE LIQUID	FAIL

D. REACTIVITY
   Water
   Acid
   Alkali

E. Dichlorodifluoromethane(%) <0.01   Trichlorofluoromethane(%) <0.01   Bromoform(%) <0.01

ATTACHMENT 2

Constituent	Total lb/yr	Percent of Total
hc*	3208730	16.8
Cresol* (cresylic acid)	998281	5.2
Toluene	770291	4.0
MEK*	676259	3.5
Methanol	586938	3.1
Acetone* (Methyl ketone)	555858	2.9
Cyclohexanone	482451	2.5
Ethyl acrylate	466761	2.4
Butanol*	464645	2.4
Xylene	448321	2.3
MIBK	422393	2.2
Tetrachlorobenzene*	410043	2.1
Nitrobenzene	382090	2.0
Ethyl benzene	364159	1.9
Pyridine	354015	1.8
2 Ethoxyethanol*	351715	1.8
Alcohols	338208	1.8
2 Nitropropane	321555	1.7
Isobutanol	238633	1.2
Dichlorobenzene*	206838	1.1
Creyslic acid	178823	0.9
heptane*	178323	0.9
Benzene	174406	0.9
Trichloroethane*	153251	0.8
Carbon	149376	0.8
Cyclohexane	144739	0.8
Chlor. paraffin oils and waxes	141435	0.7
Tetrahydrofuran	125396	0.7
Diethyl phthalate	122429	0.6
Creosote	110180	0.6
1,4 Dioxane	107045	0.6
Carbon tetrachloride	104285	0.5
Formaldehyde	100677	0.5
Trichloroethylene	100350	0.5
Cumene	99450	0.5
Ethanol	98523	0.5
Naphthalene	92408	0.5
Chloroform*	90589	0.5
Tetrachloroethylene	88399	0.5
1,1,2 Trichloro 1,2,2 triflouroethane	85377	0.4
Phenol	84824	0.4
Dinitrotoluene*	79191	0.4
Acetonitrile	78284	0.4
Chlorobenzene	76207	0.4
Isopropanol*	72266	0.4
Methyl methacrylate	71012	0.4
TCFM	69874	0.4
Formic acid	69352	0.4
Acetophenone	66350	0.3
Maleic anhydride	59443	0.3
Dichlorodifluoromethane	58810	0.3
Furfural	57915	0.3
Resorcinol	57438	0.3
Benzidine	55116	0.3

* Based on waste profiles for first year of operations.

Constituent	Total lb/yr	Percent of Total
Calcium chromate	54606	0.3
crylonitrile	54259	0.3
Dimethylphenol*	53872	0.3
Epichlorohydrin	52628	0.3
N-nitrosodiethanolamine	51860	0.3
Dimethylphthalate	51672	0.3
Toluenediamine	51594	0.3
Tetrachloroethane*	50480	0.3
Toluene diisocyanate	50350	0.3
dichloroethene*	49317	0.3
Chlorinated fluorocarbons (assumed dichlorodifluoroethane)	49180	0.3
Carbon disulfide	45647	0.2
Phthalic anhydride	44878	0.2
Dimethylamine	44654	0.2
Trichlorobenzene*	44001	0.2
Dimethyl phthalate	41680	0.2
2 Acetylaminofluorene	40513	0.2
1,2 Benzenedicarboxylic acid	40427	0.2
butyl acetate*	39330	0.2
N-nitrosopyrrolidine	38548	0.2
2 Naphthylamine	38548	0.2
Hydrazine	38412	0.2
Crotonaldehyde	37304	0.2
Dimethyl sulfate	37304	0.2
Dichloroethane* (Ethylidene dichloride)	36854	0.2
1 Naphthylamine	36583	0.2
Aniline	36020	0.2
osafrole	35777	0.2
Dimethylhydrazine*	34261	0.2
dibromoethane*	33724	0.2
N-nitrosodiethylamine	33339	0.2
Benzo(a)pyrene	33257	0.2
Chrysene	33256	0.2
N-nitrosodi-n-butylamine	32482	0.2
Fluoranthene	32012	0.2
Indeno (1,2,3-cd) pyrene	32012	0.2
3 Methylcholanthrene	32012	0.2
P-benzoquinone	32012	0.2
2 Picoline	32012	0.2
3,3' Dimethylbenzidine	32012	0.2
1,2,5,6 Dibenzanthracene (dibenz (a,c) anthracene)	32012	0.2
P-nitrophenol	32012	0.2
1 Methylbutadiene	32012	0.2
2 Acetylaminofluorene	31430	0.2
Diethyl stilbestrol	31397	0.2
Dihydrosafrole	31397	0.2
P-dimethylaminoazobenzene	31245	0.2
Paraldehyde	31222	0.2
N-nitroso-n-methylurethane	30854	0.2
N-nitroso-n-methylurea	30854	0.2
Safrole	30790	0.2
Phenacetin	30769	0.2
Dibromomethane* (Methylene bromide)	30769	0.2
Nitro-o-toluidine	30768	0.2

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* Based on waste profiles for first year of operations.

Appendix III-1
Attachment 2   2

External Release Draft
Do Not Cite or Quote

Constituent	Total lb/yr	Percent of Total
4 Bromophenyl phenyl ether	30768	0.2
diphenylhydrazine*	30768	0.2
Streptozotocin	30768	0.2
Reserpine	30768	0.2
Amitrole	30768	0.2
Cyanogen bromide	30768	0.2
Maleic hydrazide	30768	0.2
Hydrogen fluoride	30768	0.2
Auramine	30768	0.2
N,N-diethylhydrazine (1,2-diethylhydrazine)	30768	0.2
3,3' Dimethoxybenzidine	30768	0.2
L-serine	30768	0.2
Ethylene dibromide	30768	0.2
2,2 Bioxirane	30768	0.2
Acetates	30645	0.2
Acrylamide	30001	0.2
Ethyl methanesulfonate	30001	0.2
Methacrylonitrile	28808	0.2
Malononitrile	28803	0.2
Barium salt	27079	0.1
Daunomycin	26507	0.1
Acrylic acid	26033	0.1
Ethylene glycol	24861	0.1
Hexachloro 1,3 butadiene*	24646	0.1
Dichlorophenol*	23783	0.1
Acetaldehyde	23690	0.1
Polysiloxanes	20735	0.1
Hexachloroethane	20218	0.1
2 Methoxyethanol	19610	0.1
Chlordane	19053	0.1
Lead salt	18302	0.1
Dibromoethane	18004	0.1
Calcium salt	17714	0.1
Chlorophenol*	15574	0.1
Butenal*	15323	0.1
Citric acid	15043	0.1
Lindane	14696	0.1
Benzenesulfonyl chloride	14464	0.1
Dipropylamine	13087	0.1
N-butylamine	13073	0.1
2 Heptanone	13073	0.1
Amyl acetate	13073	0.1
trichloroethane	12855	0.1
Pentachlorobenzene	12570	0.1
dichloropropene*	11594	0.1
2,4 D salts and esters	10405	0.1
Acetic acid	10180	0.1
2 Chloroethyl vinyl ether	9275	0.0
1,2 Benzanthracene (benzo (a) anthracene)	9169	0.0
4,4' Methylenebis(2-chloro)aniline	8929	0.0
Chloromethyl methyl ether	8928	0.0
dichlorobutene*	8928	0.0
Pentachloroethane	8928	0.0
3,3' Dichlorobenzidine	8928	0.0

Appendix III-1

Attachment 2   3

External Release Draft

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Constituent	Total lb/yr	Percent of Total
b-chlornaphthalene	8928	0.0
-chloro-m-cresol	8849	0.0
Hexachloropropene	8714	0.0
chloral (Trichloroacetaldehyde)	8708	0.0
Antimony salt	8687	0.0
Arsenic salt	8687	0.0
Ethyl methacrylate	8683	0.0
Pronamide	8669	0.0
Tris (2,3 dibromopropyl) phosphate	8659	0.0
1.2 Dibromo-3-dichloropropane	8582	0.0
Acetyl chloride	8582	0.0
Benzotrichloride	8582	0.0
Chlorambucil	8582	0.0
Chlornaphazine	8582	0.0
Cyclophosphamide (2H-1,3,2 Oxazaphosphorin-2-amine)	8582	0.0
Melphalan	8582	0.0
O-toluidine hydrochloride	8582	0.0
DDT	8582	0.0
Benzamine, 4 chloro 2 methyl-	8582	0.0
Dichloromethoxy ethane	8582	0.0
Dimethylcarbamoyl chloride	8582	0.0
Hexachlorophene	8582	0.0
Thallium chloride	8494	0.0
DDD	8367	0.0
Dichloroisopropyl ether	8367	0.0
Pentachloronitrobenzene	8327	0.0
Kepone	7819	0.0
etones*	7554	0.0
Propanol*	7304	0.0
Thiourea*	7102	0.0
Ethylene Oxide* (Oxirane)	6906	0.0
Heptachlor	6904	0.0
Tribromomethane	6816	0.0
Copper	6787	0.0
Mixed organics (alc., amine, etc.)	6651	0.0
Ethyl ether* (Diethyl ether)	6577	0.0
Cycloheptane	6537	0.0
octanone*	6537	0.0
2 Hexanone	6537	0.0
Decanes	6537	0.0
3 Pentanone	6537	0.0
2 Pentanone	6537	0.0
Styrene	6537	0.0
2 Octanone	6537	0.0
Phosphoric acid	6465	0.0
Furfuran (furan)	6139	0.0
Anhydride	6113	0.0
Di-n-propylnitrosamine	5504	0.0
Acetaldehyde* (Ethanal)	5371	0.0
Vinyl chloride	5230	0.0
Trichlorofluoroethane	4896	0.0
Dibenzo(a,i)pyrene	4604	0.0
O,o-diethyl-s-methyldithiophosphate	4449	0.0
Aethanethiol (Thiomethanol)	4364	0.0

* Based on waste profiles for first year of operations.

Constituent	Total lb/yr	Percent of Total
Methylthiouracil	4276	0.0
Saccharin and salts	4276	0.0
Selenium sulfide	4276	0.0
1,3 Propane sultone	4276	0.0
Lasiocarpine	4261	0.0
Thiram	4233	0.0
Trypan blue	4066	0.0
Thioacetamide	4003	0.0
Water	3537	0.0
Trichlorophenol*	3481	0.0
Sulfuric acid	2462	0.0
Bis(2)chloroethyl ether* ('Dichloroethyl ether)	2302	0.0
Lead subacetate	2286	0.0
Zinc	2171	0.0
Hexachlorocyclopentadiene	2170	0.0
Lead acetate	1969	0.0
Malonitrile hydroazide*	1965	0.0
Chrome compounds	1869	0.0
2,3,4,6 Tetrachlorophenol	1823	0.0
4,4' Methylenebis(2chloro)benzeneamine	1823	0.0
Potassium hydroxide	1663	0.0
Benzal chloride	1334	0.0
Sodium bicarbonate	1304	0.0
Chlorobenzilate	1188	0.0
Diallate	1188	0.0
Lithium amide	1158	0.0
Pentachlorophenol	1155	0.0
Bromoform*	959	0.0
Pyrene	909	0.0
1,2 Ethanediylbiscarbamodithioic acid	909	0.0
Potassium-t-butoxide	817	0.0
Mitomycin C (Azirino)	767	0.0
Methoxychlor	669	0.0
Barium	493	0.0
Lead	472	0.0
Endrin	455	0.0
N-nitroso-n-ethylurea	428	0.0
Creosol	393	0.0
Phosphorus sulfide	331	0.0
Thioacetamine*	273	0.0
Lead phosphate	260	0.0
Chromium	244	0.0
Thallium carbonate	230	0.0
Thallium acetate	230	0.0
Thallium nitrate	224	0.0
Bis(2)chloroisopropyl ether* (Dichloroisopropyl ether)	214	0.0
2,4 Dichlorophenoxyacetic acid (2,4-D)	127	0.0
2,4,5 TP (Silvex)	127	0.0
Sodium sulfide	111	0.0
Toxaphene	110	0.0
Ethylene bis-dithiocarbamic acid	107	0.0
Silver	94	0.0
Methyl ethyl ketone peroxide	86	0.0
Cadmium	76	0.0

Constituent	Total lb/yr	Percent of Total
Arsenic	45	0.0
Selenium dioxide	24	0.0
PCBs	23	0.0
Cacodylic acid	15	0.0
Mercury	10	0.0
Selenium	3	0.0
Nitrophenol*	3	0.0
Dioctyl phthalate	3	0.0
Dichloromethane * (Methylene chloride)	2	0.0
Hexachlorobenzene	2	0.0
Dipropylnitrosamine	1	0.0
N-propylamine (1-aminopropane)	0	0.0
Chromoform	0	0.0
N-methyl-n'-nitro-n-nitrosoguanidine	0	0.0
Phenanthrene	0	0.0
Ethyl carbamate (urethane)	0	0.0
Methyl chlorocarbonate	0	0.0
7,12 Dimethyl benz(a)anthracene	0	0.0
Azaserine	0	0.0
Sym-trinitrobenzene	0	0.0
Ethylene thiourea	0	0.0
Methapyrilene hydrochloride	0	0.0
2 Chloronaphthalene	0	0.0
Bis(2 chloroethoxy)methane	0	0.0
Bis(2)chloroethyl ether* ('Dichloroethyl ether)	0	0.0
Dimethylcarbamyl chloride	0	0.0
Benz(c)acridine	0	0.0
,2 Propanediol	0	0.0
1,3 Pentadiene	0	0.0
1,2,7,8 Dibenzopyrene	0	0.0
1,2,3,4 Diepoxybutane	0	0.0
4 Chloro-o-toluidine hydrochloride	0	0.0
Hydrochloric acid	0	0.0
Iodomethane* (Methyl iodide)	0	0.0
Total of cmpds remaining after revision	19143596	100.0

Summary of Values	Theoretical	Actual
total lbs cmpds containing analytes	2544153	2507702
total lbs pumpable feed, less ash & batts	19127250	
mass %	64	
ash lbs	1498252	
total (with ash)	20625502	
mass % (pumpables)	69	

* Based on waste profiles for first year of operations.

Appendix III-1
Attachment 2   6

Constituent	Total lb/yr	Percent of Total
Xylene	688977	12.2
Isobutanol	522564	9.3
hc*	348828	6.2
Hexane	329211	5.8
Toluene	323755	5.7
MEK	262653	4.7
MIBK	228362	4.1
Acetone	221834	3.9
Ketones*	191136	3.4
Pyridine	125649	2.2
trichloroethane	106504	1.9
Ethyl acetate	100705	1.8
Aniline	99145	1.8
cresol*	82414	1.5
Ethyl benzene	66116	1.2
2 Nitropropane	65636	1.2
Benzene	65614	1.2
Formaldehyde	62035	1.1
Chlorinated fluorocarbons	57022	1.0
Tetrahydrofuran	53530	0.9
Chlorobenzene	53359	0.9
Acetaldehyde	51724	0.9
N-nitrosopyrrolidine	51213	0.9
Benz(c)acridine	51174	0.9
Cacodylic acid	49898	0.9
Mitomycin C (Azirino)	49898	0.9
Nitrobenzene	49564	0.9
Cyclohexane	47888	0.8
2 Ethoxyethanol	47706	0.8
Acrylic acid	47358	0.8
Dimethylhydrazine*	45364	0.8
Ethyl methacrylate	44091	0.8
Di-n-propylnitrosamine	44088	0.8
Dipropylamine	44088	0.8
Lasiocarpine	44088	0.8
Lead phosphate	44088	0.8
Lead acetate	43445	0.8
Chlorinated polymer resins (PVC)	41458	0.7
Butanol	33098	0.6
Dichlorobenzene*	31743	0.6
Phthalic anhydride	29782	0.5
Cresylic acid	29367	0.5
Acetonitrile	28848	0.5

* Based on waste profiles for first year of operation.

Appendix III-1
Attachment 2   7

External Release Draft
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Constituent	Total lb/yr	Percent of Total
Chrome compounds	27658	0.5
Dimethylamine	26512	0.5
Cyclohexanone	26421	0.5
1,4 Dioxane*	25502	0.5
1 Naphthylamine	25488	0.5
1,2 Benzenedicarboxylic acid	25488	0.5
2 Naphthylamine	25488	0.5
Dimethyl sulfate	25488	0.5
Sodium hydroxide	22298	0.4
Antimony salt	21564	0.4
Arsenic salt	21564	0.4
Methanol	20534	0.4
Carbon disulfide	18709	0.3
Acetic acid	18662	0.3
Tetrachloroethylene	17608	0.3
Trichloroethylene	16928	0.3
1,1,2 Trichloro 1,2,2 triflouroethane	14391	0.3
Formic acid	13188	0.2
Carbon tetrachloride	12794	0.2
Acetophenone	12338	0.2
Dimethylphthalate	11062	0.2
Calcium salt	10980	0.2
Lead salt	10290	0.2
Vinyl chloride	9926	0.2
Citric acid	9919	0.2
Benzal chloride	9311	0.2
Methoxychlor	9311	0.2
dichloropropene*	9168	0.2
Chlorobenzilate	8669	0.2
Diallate	8669	0.2
Tetrachloroethane*	7213	0.1
Daunomycin	7086	0.1
Chloroform*	6865	0.1
2,4 Dichlorophenoxyacetic acid (2,4-D)	5012	0.1
4,4' Methylenebis(2-chloro)aniline	5012	0.1
Carbamic acid	5011	0.1
Trichlorobenzene*	4648	0.1
Isosafrole	4612	0.1
Toluene diisocyanate	4545	0.1
Toluenediamine	4545	0.1
dinitrotoluene*	4305	0.1
Furfural	3816	0.1
Dimethyl phthalate	3269	0.1

* Based on waste profiles for first year of operation.

Constituent	Total lb/yr	Percent of Total
Methacrylonitrile	3269	0.1
Sulfuric acid	2894	0.1
Furfuran (furan)	2552	0.0
Resorcinol	2540	0.0
Hexachloro 1,3 butadiene*	2505	0.0
Chlorodibromomethane	2138	0.0
Chromic acid	1961	0.0
Bromoform*	1818	0.0
Acetates	1403	0.0
Potassium-t-butoxide	1353	0.0
Acrylamide	1276	0.0
Bis(2)chloroethyl ether* ('Dichloroethyl ether)	1276	0.0
Ethyl methanesulfonate	1276	0.0
Ethylene Oxide* (Oxirane)	1276	0.0
Maleic anhydride	1276	0.0
N-nitrosodiethanolamine	1276	0.0
N-nitrosopiperidine	1276	0.0
P-dimethylaminoazobenzene	1276	0.0
Thallium nitrate	1276	0.0
Thiourea	1091	0.0
Trypan blue	1082	0.0
Diethyl phthalate	1047	0.0
Diethyl stilbestrol	1024	0.0
Dihydrosafrole	1024	0.0
Kepone	894	0.0
dichloroethane*	881	0.0
Heptachlor and hydroxide	858	0.0
Dichloromethoxy ethane	813	0.0
Chlordane	761	0.0
dichloroethene*	723	0.0
Pentachlorophenol	707	0.0
Pentachloronitrobenzene	705	0.0
Tetrachlorobenzene*	581	0.0
P-chloro-m-cresol	500	0.0
Calcium sulfide	438	0.0
Thiram	422	0.0
Dibromoethane	403	0.0
Methanethiol (Thiomethanol)	339	0.0
Hexachloropropene	251	0.0
Benzenesulfonyl chloride	251	0.0
DDD	251	0.0
Pronamide	251	0.0
Thallium chloride	251	0.0

* Based on waste profiles for first year of operation.

Constituent	Total lb/yr	Percent of Total
Thioacetamide	250	0.0
Benzamine, 4 chloro 2 methyl-	206	0.0
Pentachlorobenzene	206	0.0
Dichlorophenol*	201	0.0
4-Chloro-o-toluidine ('Benzamine, 4 chloro 2 methyl-)	201	0.0
N-nitroso-di-n-ethanolamine	144	0.0
N-nitroso-n-ethylurea	144	0.0
Tris (2,3 dibromopropyl) phosphate	75	0.0
Toxaphene	20	0.0
Ethyl ether (Diethyl ether)	19	0.0
2 Acetylaminofluorene	11	0.0
Dichlorodifluoromethane	4	0.0
5 Nitro-o-toluidine	3	0.0
Bis(2 ethylhexyl)phthalate	3	0.0
Safrole	3	0.0
Totals	5637846	100.0

ATTACHMENT 3

ATTACHMENT 3: PREDICTION OF SPECIATION

Table 3-1 of this attachment summarizes the major species of each metal (those which account for 1 mole percent or more of the total quantity of the metal present) of interest predicted to exist at each of the conditions examined. Many assumptions are required to produce these predictions so great care should be taken in other use of these data. The primary assumptions include:

1.   *Thermodynamic equilibrium is continuously maintained throughout the combustion system.*

This implies that there are no kinetic limitations to the reactions. However, as combustion gases cool, it is expected that kinetic limitations increase in importance and at some temperature become dominant. Thus it is unlikely that the species predicted to form at low temperatures using thermodynamic modeling would actually form in the time in which the metals remain in the incinerator and the flue gas cleaning equipment.

2.   *All elements are intimately mixed and may react with all other elements.*

Some segregation will occur. For instance, gas phase elements will have limited access to the slag. However, insufficient knowledge is available to refine the assumption.

3.   *No condensed phase interactions occur.*

This assumption is a simplification because recent testing indicates that there are significant interactions between some metals and the bulk inorganic substrate (Barton et al.) "The behavior of metals during the thermal treatment of mixed wastes," presented at the 1995 Incineration Conference, Seattle, WA, 1995). In slagging systems, non-ideal solutions of metals in the slag will occur.

4.   *Data for all species which may form are included in the thermodynamic databases used.*

The data bases are extensive; however, exclusion of even one key species can have a strong impact on the equilibrium predictions.

5.   *The species CrO_2Cl_2 will not form.*

The assumption is made to account for some kinetic limitations. Thermodynamic calculations predict that large quantities of CrO_2Cl_2 will form as the flue gases cool. However, it is strongly suspected that the reactions converting Cr_2O_3 into CrO_2Cl_2 are slow (little CrO_2Cl_2 is observed in the flue gases). To account for this observation, CrO_2Cl_2 is excluded from consideration.

6.   *The waste feed concentrations derived are correct.*
     The implications of this assumption are discussed at length in the description of modeling uncertainty analysis.

     It should be noted that the predictions pertain only to the specific conditions listed. Local temperatures and oxygen concentrations can vary significantly in an incinerator.

Table 3-1. Speciation Results From Thermodynamic Modeling

T	C	1400	1200	1100	1000	1200	1200	150	200	400	1200	150
SR[a]		1	1	1	1	0.8	1.2	1.5	1.5	1.5	1	1.5
Cl	mol/min	175	175	175	175	175	175	175	175	175	0	0
Element	Chemical Form	Portion of element having the listed form, (mole percent)										
Al												
	Al_2O_3	94	96	96	95	96	96	76	79	88	96	76
	Al_2SiO_5	3	4	4	5	4	4	24	21	12	4	24
	$AlCl$	1	0	0	0	0	0	0	0	0	0	0
	$AlCl_3$	2	0	0	0	0	0	0	0	0	0	0
As												
	As_2O_5	0	0	0	0	0	0	100	100	100	0	100
	AsO	100	100	100	100	100	100	0	0	0	100	0
Sb												
	Sb_2O_5	0	0	0	0	0	0	1				1
	SbO_2	0	0	0	0	0	0	99	100	100	0	99
	SbO	100	100	100	100	100	100	0	0	0	100	0
Ba												
	$BaCl_2$	54	74	82	87	85	67	88	88	88	0	0
	$Ba(OH)_2$	16	3	2	0	2	4	12	12	12	4	100
	BaS	0	0	0	0	8	0	0	0	0	0	0
	BaO	30	23	16	13	5	29	0	0	0	96	0
Be												
	$Be(OH)_2$	5	2	0	0	0	0	0	0	0	2	0
	BeO	95	98	100	100	100	100	100	100	100	98	100
Cd												
	Cd	89	22	3	0	27	21	0	0	0	72	0
	$CdCl$	1	1	0	0	1	1	0	0	0	0	0
	$CdCl_2$	7	68	87	90	64	69	0	0	0	0	0
	CdO	3	6	6	6	5	6	0	0	0	19	0
	$CdSO_4$	0	0	0	0	0	0	100	100	100	0	100
	$CdO \cdot SiO_2$	0	3	4	4	3	3	0	0	0	9	0
Cr												
	Cr_2O_3	100	100	100	100	100	100	100	100	100	100	100
Cu												
	$CuCl$	36	5	1	0	0	8	0	0	0	0	0
	Cu_3Cl_3	0	0	0	0	0	0	0	0	0	0	0
	Cu_2O	62	95	99	100	0	92	0	0	0	100	0
	Cu	2	0	0	0	100	0	0	0	0	0	0
	CuO	0	0	0	0	0	0	100	100	100	0	100
Pb												
	PbO	73	82	93	100	0	91	0	0	100	96	0
	$PbCl$	10	10	4	0	1	5	0	0	0	0	0
	$PbCl_2$	1	2	1	0	0	3	0	0	0	0	0
	PbS	0	0	0	0	1	0	0	0	0	0	0
	PbO_2	0	0	0	0	0	0	100	0	0	0	100
	Pb_3O_4	0	0	0	0	0	0	0	100	0	0	0
	Pb	16	6	2	0	98	1	0	0	0	6	0
Hg												
	$HgSO_4$	0	0	0	0	0	0	1	2	0	0	0

Table 3-1. Speciation Results From Thermodynamic Modeling (Continued)

	HgCl$_2$	0	0	0	0	0	0	99	98	100	0	100
	Hg	99	99	99	98	99	99	0	0	0	99	0
	HgO	1	1	1	2	1	1	0	0	0	1	0
Ni	NiCl	1	0	0	0	0	7	0	0	0	0	0
	NiCl$_2$	1	1	0	0	0	0	0	0	0	0	0
	Ni	98	99	100	100	100	93	100	100	100	100	100
	Ni$_3$S$_2$	0	0	0	0	0	0	0	0	0	0	0
Se	SeO	9	2	1	0	2	2	0	0	0	2	0
	SeO$_2$	91	98	99	100	98	98	100	100	.100	98	100
Ag	Ag	1	0	0	0	0	0	0	0	0	100	0
	AgCl	99	100	100	100	100	100	0	0	0	0	0
	Ag$_2$SO$_4$	0	0	0	0	0	0	100	100	100	0	100
Tl	Tl	0	0	0	0	0	0	0	0	0	100	0
	TlCl	100	100	100	100	100	100	0	0	76	0	0
	Tl$_2$SO$_4$	0	0	0	0	0	0	100	100	24	0	100
Zn	Zn	100	100	100	100	100	100	92	92	92	100	92
	ZnSO$_4$	0	0	0	0	0	0	8	8	8	0	8

SR^a = Air to waste stoichiometric ratio.

ATTACHMENT 4

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
	CARCINOGENS								
	PCDD/PCDF TEQ								2.38E-09
764-41-0	(trans)1,4-Dichloro-2-butene								0.00E+00
79-34-5	1,1,2,2-Tetrachloroethane			2.15E-04		1.29E-05			2.15E-04
79-00-5	1,1,2-Trichloroethane					1.29E-05			1.29E-05
75-34-3	1,1-Dichloroethane [WTI PIC LIST]					1.29E-05			1.29E-05
75-35-4	1,1-Dichloroethylene (vinylidine Chloride)					1.29E-05			1.29E-05
95-50-1	1,2-Dichlorobenzene			8.90E-04	3.31E-05		2.66E-05		8.90E-04
107-06-2	1,2-Dichloroethane					1.29E-05			1.29E-05
78-87-5	1,2-Dichloropropane [WTI PIC LIST]					1.29E-05			1.29E-05
106-99-0	1,3-Butadiene								0.00E+00
95-50-1	1,3-Dichlorobenzene					1.29E-05		6.69E-06	1.29E-05
106-46-7	1,4-Dichlorobenzene					1.29E-05	1.02E-05		1.29E-05
88-06-2	2,4,6-Trichlorophenol							6.69E-06	6.69E-06
121-14-2	2,4-Dinitrotoluene							6.69E-06	6.69E-06
606-20-2	2,6-Dinitrotoluene							6.69E-06	6.69E-06
91-94-1	3,3'-Dichlorobenzidine			3.33E-05				6.69E-06	3.33E-05
107-02-8	Acrolein								0.00E+00
107-13-1	Acrylonitrile			2.02E-04					2.02E-04
71-43-2	Benzene	3.59E-04	7.17E-03	8.95E-04					7.17E-03
50-32-8	Benzo(a)pyrene			1.24E-04				6.69E-06	1.24E-04
205-99-2	Benzo(b)fluoranthene							6.69E-06	6.69E-06
111-44-4	Bis(2-chloroethyl)ether [WTI PIC LIST]			1.33E-05				6.69E-06	1.33E-05
39638-32-9	Bis(2-chloroisopropyl)ether [WTI PIC LIST]			7.98E-07				6.69E-06	6.69E-06
117-81-7	Bis(2-ethylhexyl)phthalate			1.12E-08			4.52E-05		4.52E-05
75-27-4	Bromodichloromethane				1.23E-04				1.23E-04
75-25-2	Bromoform			1.04E-05	9.01E-05				9.01E-05
85-66-7	Butylbenzyl phthalate							6.69E-06	6.69E-06
56-23-5	Carbon tetrachloride				4.37E-04	6.05E-04			6.05E-04
57-74-9	Chlordane			7.39E-05					7.39E-05
67-66-3	Chloroform	6.10E-04	4.08E-04	3.63E-04					6.10E-04
74-87-3	Chloromethane				4.22E-05				4.22E-05

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
218-01-9	Chrysene			1.24E-04				6.69E-06	1.24E-04
124-48-1	Dibromochloromethane [WTI PIC LIST]				2.63E-05				2.63E-05
106-93-4	Ethylene dibromide			1.15E-04					1.15E-04
75-21-8	Ethylene oxide			3.05E-05					3.05E-05
86-73-7	Fluorene [WTI PIC LIST]							6.69E-06	6.69E-06
50-00-0	Formaldehyde			6.07E-04					6.07E-04
76-44-8	Heptachlor			2.57E-05					2.57E-05
118-74-1	Hexachlorobenzene			6.23E-09				6.69E-06	6.69E-06
87-68-3	Hexachlorobutadiene			1.01E-04				6.69E-06	1.01E-04
77-47-4	Hexachlorocyclopentadiene			8.09E-06				6.69E-06	8.09E-06
67-72-1	Hexachloroethane			7.54E-05				6.69E-06	7.54E-05
78-59-1	Isophorone [WTI PIC LIST]							6.69E-06	6.69E-06
75-09-2	Methylene chloride				5.20E-04				5.20E-04
86-30-6	N-Nitrosodiphenylamine [WTI PIC LIST]							6.69E-06	6.69E-06
1336-36-3	Polychlorinated biphenyls (209 congeners)								0.00E+00
127-18-4	Tetrachloroethylene	1.05E-02	1.76E-04	3.95E-04					1.05E-02
79-01-6	Trichloroethylene			4.37E-04					4.37E-04
108-05-4	Vinyl acetate					6.43E-05			6.43E-05
75-01-4	Vinyl chloride			5.65E-05		1.29E-05			5.65E-05
95-53-4	o-Toluidine								0.00E+00
106-47-8	p-Chloroaniline							6.69E-06	6.69E-06
106-49-0	p-Toluidine								0.00E+00
58-89-9	-Hexachlorocyclohexane (Lindane)			5.48E-05					5.48E-05

NON-CARCINOGENS									
542-75-6	(cis)1,3-Dichloropropene					1.29E-05			1.29E-05
764-41-0	(cis)1,4-Dichloro-2-butene								0.00E+00
156-80-5	(trans)1,2-dichloroethylene					1.29E-05			1.29E-05
542-75-6	(trans)1,3-Dichloropropene					1.29E-05			1.29E-05
630-20-6	1,1,1,2-Tetrachloroethane								0.00E+00
71-55-6	1,1,1-Trichloroethane				4.45E-05				4.45E-05
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane			3.30E-04					3.30E-04

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
96-18-4	1,2,3-Trichloropropane								0.00E+00
95-94-3	1,2,4,5-Tetrachlorobenzene								0.00E+00
120-82-1	1,2,4-Trichlorobenzene						1.45E-04		1.45E-04
96-12-8	1,2-Dibromo-3-chloropropane			0.00E+00					0.00E+00
99-65-0	1,3-Dinitrobenzene								0.00E+00
123-39-1	1,4-Dioxane			4.94E-04					4.94E-04
	1-Methyl-2-pentanone [WTI PIC LIST]								0.00E+00
58-90-21	2,3,4,6-Tetrachlorophenol			6.80E-06					6.80E-06
95-95-4	2,4,5-Trichlorophenol							6.69E-06	6.69E-06
94-75-7	2,4-D			3.88E-05					3.88E-05
120-83-2	2,4-Dichlorophenol							6.69E-06	6.69E-06
105-67-9	2,4-Dimethylphenol							6.69E-06	6.69E-06
51-28-5	2,4-Dinitrophenol [WTI PIC LIST]							6.69E-06	6.69E-06
78-93-3	2-Butanone [WTI PIC LIST]					6.43E-05			6.43E-05
532-27-4	2-Chloroacetophenone								0.00E+00
95-57-8	2-Chlorophenol							6.69E-06	6.69E-06
75-29-6	2-Chloropropane								0.00E+00
591-78-6	2-Hexanone [WTI PIC LIST]			2.44E-05		6.43E-05			6.43E-05
91-57-6	2-Methylnaphthalene [WTI PIC LIST]						4.18E-05		4.18E-05
95-48-7	2-Methylphenol [WTI PIC LIST]							6.69E-06	6.69E-06
88-74-4	2-Nitroaniline							6.69E-06	6.69E-06
88-75-5	2-Nitrophenol [WTI PIC LIST]							6.69E-06	6.69E-06
	2-chloronaphthalene			8.91E-11				6.69E-06	6.69E-06
119-90-4	3,3'-Dimethoxybenzidine			1.15E-04					1.15E-04
99-09-2	3-Nitroaniline [WTI PIC LIST]							6.69E-06	6.69E-06
	4,6-Dinitro-2-methylphenol [WTI PIC LIST]							6.69E-06	6.69E-06
59-50-7	4-Chloro-3-methylphenol [WTI PIC LIST]							6.69E-06	6.69E-06
	4-Methyl-2-Pentanone					6.43E-05			6.43E-05
100-01-6	4-Nitroaniline [WTI PIC LIST]							6.69E-06	6.69E-06
100-02-7	4-Nitrophenol							6.69E-06	6.69E-06
83-32-9	Acenaphthene [WTI PIC LIST]							6.69E-06	6.69E-06
208-96-8	Acenaphthylene [WTI PIC LIST]							6.69E-06	6.69E-06

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
75-07-0	Acetaldehyde			3.01E-04					3.01E-04
67-64-1	Acetone [WTI PIC LIST]			2.90E-03	5.86E-04				2.90E-03
98-86-2	Acetophenone			2.93E-04					2.93E-04
120-12-7	Anthracene							6.69E-06	6.69E-06
100-52-7	Benzaldehyde								0.00E+00
56-55-3	Benzo(a)anthracene			3.42E-05				6.69E-06	3.42E-05
	Benzo(e)pyrene								0.00E+00
191-24-2	Benzo(g,h,i)perylene							6.69E-06	6.69E-06
	Benzo(j)fluoranthene								0.00E+00
207-08-9	Benzo(k)fluoranthene							6.69E-06	6.69E-06
65-85-0	Benzoic acid [WTI PIC LIST]						1.13E-05		1.13E-05
96-07-7	Benzotrichloride			3.20E-05					3.20E-05
100-44-7	Benzyl chloride								0.00E+00
92-52-4	Biphenyl								0.00E+00
111-91-1	Bis(2-chloroethoxy)methane [WTI PIC LIST]			8.91E-11				6.69E-06	6.69E-06
	Bromochloromethane								0.00E+00
590-60-2	Bromoethene								0.00E+00
74-83-9	Bromomethane				2.28E-05				2.28E-05
101-55-3	Bromophenyl phenylether [WTI PIC LIST]							6.69E-06	6.69E-06
75-15-0	Carbon disulfide [WTI PIC LIST]			2.40E-04	1.83E-04				2.40E-04
106-90-7	Chlorobenzene			4.83E-04	6.39E-05				4.83E-04
510-15-6	Chlorobenzilate			3.68E-05					3.68E-05
75-00-3	Chloroethane [WTI PIC LIST]					1.29E-05			1.29E-05
7005-72-3	Chlorophenyl phenylether [WTI PIC LIST]							6.69E-06	6.69E-06
4170-30-3	Crotonaldehyde			1.39E-04					1.39E-04
3547-04-4	DDE								0.00E+00
117-84-0	Di(n)octyl phthalate							6.69E-06	6.69E-06
53-70-3	Dibenz(a,h)anthracene							6.69E-06	6.69E-06
84-74-2	Dibutyl phthalate [WTI PIC LIST]						2.50E-05		2.50E-05
75-71-8	Dichlorodifluoromethane			2.19E-04					2.19E-04
	Dichlorofluoromethane [D & O PIC LIST]								0.00E+00
84-66-2	Diethyl phthalate			4.60E-04			2.23E-05		4.60E-04

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
131-11-3	Dimethyl phthalate			1.68E-04				6.69E-06	1.68E-04
100-41-4	Ethylbenzene			1.60E-03	2.69E-05				1.60E-03
96-45-7	Ethylene thiourea			1.46E-10					1.46E-10
75-34-3	Ethylidene dichloride								0.00E+00
206-44-0	Fluoranthene			1.19E-04				6.69E-06	1.19E-04
70-30-4	Hexachlorophene			3.20E-05					3.20E-05
193-39-5	Indeno(1,2,3-cd)pyrene			1.19E-04				6.69E-06	1.19E-04
123-33-1	Maleic hydrazide			1.15E-04					1.15E-04
72-43-5	Methoxychlor			3.72E-05					3.72E-05
71-55-6	Methyl chloroform				7.13E-05				7.13E-05
78-93-3	Methyl ethyl ketone			3.50E-03					3.50E-03
106-87-2	Methylcyclohexane								0.00E+00
74-95-3	Methylene bromide								0.00E+00
924-16-3	N-Nitroso-di-n-butylamine			1.21E-04					1.21E-04
91-20-3	Naphthalene			3.45E-04			1.02E-05		3.45E-04
96-95-3	Nitrobenzene			1.61E-03				6.69E-06	1.61E-03
621-64-7	Nitroso-di-n-propylamine [WTI PIC LIST]							6.69E-06	6.69E-06
608-93-5	Pentachlorobenzene			4.76E-05					4.76E-05
82-68-8	Pentachloronitrobenzene			3.37E-05					3.37E-05
87-86-5	Pentachlorophenol			6.94E-06				6.69E-06	6.94E-06
85-01-8	Phenanthrene [WTI PIC LIST]			3.39E-10				6.69E-06	6.69E-06
108-95-2	Phenol			3.16E-04				6.69E-06	3.16E-04
75-44-5	Phosgene								0.00E+00
123-36-6	Propionaldehyde								0.00E+00
78-87-5	Propylene dichloride								0.00E+00
129-00-0	Pyrene [WTI PIC LIST]			3.39E-06				6.69E-06	6.69E-06
91-22-5	Quinoline								0.00E+00
106-51-4	Quinone								0.00E+00
94-59-7	Safrole (5-(2-Propenyl)-1,3-benzodioxole)			1.15E-04					1.15E-04
	Selenium			1.28E-08					1.28E-08
100-42-5	Styrene			2.44E-05	1.66E-05				2.44E-05
106-88-3	Toluene			4.08E-03	1.96E-04				4.08E-03

Attachment 4. Estimated Emission Rates for Organic Compounds

CAS No.	Chemical Name	Emission Rates, g/s							Maximum Emission Rate, g/s
		1A	1B	2	3A	3B	4A	4B	
75-69-4	Trichlorofluoromethane				4.80E-04				4.80E-04
	m,p-Xylene				1.10E-04				1.10E-04
1319-77-3	m-Cresol								0.00E+00
1330-20-7	m-Xylene (m-Dimethyl benzene)								0.00E+00
110-54-3	n-Hexane								0.00E+00
1319-77-3	o-Cresol								0.00E+00
528-29-0	o-Dinitrobenzene								0.00E+00
1330-20-7	o-Xylene (o-Dimethyl benzene)				3.37E-05				3.37E-05
1319-77-3	p-Cresol							6.69E-06	6.69E-06
100-25-4	p-Dinitrobenzene								0.00E+00
1330-20-7	p-Xylene (p-Dimethyl benzene)								0.00E+00
319-84-6	-Hexachlorocyclohexane								0.00E+00
91-58-7	-Chloronaphthalene								0.00E+00
319-85-7	-Hexachlorocyclohexane								0.00E+00
	Total			2.38E-02					4.30E-02

Sources:

1A--3 Measured PIC's, Condition 2 of March '93 trial burn

1B--3 Measured PIC's, February '94 retest of trial burn Condition 2

2--DRE's applied to waste profile data, DRE's from Condition 2 of March '93 trial burn

3A--Other volatile PIC's, February '94 retest of Condition 2 (measured)

3B--Other volatile PIC's, February '94 retest of Condition 2 (non-detected, emission rates are based on detection limits)

4A--Other semi-volatile PIC's, February '94 retest of Condition 2 (measured)

4B--Other semi-volatile PIC's, February '94 retest of Condition 2 (non-detected, emission rates are based on detection limits)

ATTACHMENT 5

ATTACHMENT

WASTE FEED CUTOFF PERFORMANCE CATEGORIES
WASTE TECHNOLOGIES INDUSTRIES
EAST LIVERPOOL, OHIO

CLNK   Waste Feed Cutoffs (WFCOs) under this category are caused by clinkers falling into the slag quench, typically resulting in elevated SCC pressure.

CTRL   This category is comprised of WFCOs caused by a failure of control equipment, including the Bailey system and the Continuous Emissions Monitoring System (CEMS). Examples of causes under this category include: CEMS analyzer failure; CEMS computer failure; CEMS calibration; and transmitter (e.g., thermocouple) failure.

ESP   This category of WFCOs are caused by conditions in the Electrostatic Precipitator (ESP).

FEED   Under this category, the characteristics of the waste fed to the incinerator contributed to the WFCOs.

FLOW   This category covers WFCOs caused by the flow from the lances. WFCOs under this category may be caused by: variations in flow; inadequate flow; loss of flow; switching tanks; plugged lances, pump failure; clogged strainers; and lance purges.

LMT   For this category, either no clear cause for the WFCO is provided or the WFCO is caused by a prior WFCO.

MAIN   WFCOs under this designation are caused by maintenance activities.

MISC   This category covers WFCOs not included in other categories.

SCRB   Under this category, WFCOs are caused by conditions in the scrubber.

SD   WFCOs under this category are associated with the spray dryer. These typically involve a loss of flow from the spray dryer's atomizers.

WASTE FEED CUTOFF PERFORMANCE SUMMARY
WASTE TECHNOLOGIES INDUSTRIES
EAST LIVERPOOL, OHIO

Description	Date								
	11/93	12/93	1/94	2/94	3/94	4/94	5/94	6/94	7/94
CLNK	0	0	3	1	1	12	14	11	6
CTRL	8	5	4	2	10	10	2	1	5
ESP	3	1	1	1	1	0	0	0	0
FEED	14	3	5	4	4	16	25	7	8
FLOW	9	14	12	15	5	20	22	1	6
LMT	11	6	1	0	1	4	8	1	3
MAIN	1	0	0	1	2	1	0	0	0
MISC	6	4	3	0	5	2	11	3	2
SCRB	2	2	1	0	3	3	2	0	1
SD	5	0	0	2	1	5	1	0	0
Total	59	35	30	26	33	73	85	24	31
Hazardous Waste Hours	477	295	352	407	360	532	451	255	334
Avg. Hours Between WFCOs	8.08	8.43	11.73	15.65	10.91	7.29	5.31	10.63	10.77

Source: Waste Technologies Industries, Report of AWFCO Incidences to Ohio EPA, 1994.

Note: Table 1 provides specific information on positive pressure AWFCOs as identified by the facility.

ATTACHMENT 6

Identification
    Identification No.:   B&H
    City: Pittsburgh
    State: PA
    Company: WTI
    Type of Tank: Vertical Fixed Roof

Tank Dimensions
    Shell Height (ft):   34
    Diameter (ft):   10
    Liquid Height (ft):   34
    Avg. Liquid Height (ft):   33
    Volume (gallons):   19978
    Turnovers: 739
    Net Throughput (gal/yr):   14617282

Paint Characteristics
    Shell Color/Shade: White/White
    Shell Condition: Good
    Roof Color/Shade: White/White
    Roof Condition: Good

Roof Characteristics
    Type: Cone
    Height (ft):   0.00
    Radius (ft) (Dome Roof):   0.00
    Slope (ft/ft) (Cone Roof): 0.0000

Breather Vent Settings
    Vacuum Setting (psig):   0.00
    Pressure Setting (psig):   0.00

Meteorological Data Used in Emission Calculations: Pittsburgh, Pennsylvania

Mixture/Component	Month	Daily Liquid Temperatures (deg F)			Surf. Liquid Bulk Temp. (deg F)	Vapor Pressures (psia)			Vapor Mol. Weight	Liquid Mass Fract.	Vapor Mass Fract.	Mol. Weight	Basis for Vapor Pressure Calculations
		Avg.	Min.	Max.		Avg.	Min.	Max.					
	All	51.75	47.02	56.48	50.32	0.5354	0.4818	0.5969	44.933				
Octane (-n)						0.1228	0.1054	0.1426		0.2777	0.0752	114.23	Option 1
Cresol (-o)						0.0011	0.0008	0.0015		0.1018	0.0003	108.14	Option 2: A=6.9110, B=1435.500, C=165.160
Toluene						0.2540	0.2176	0.2956		0.0666	0.0373	92.13	Option 2: A=6.9540, B=1344.800, C=219.480
Methyl alcohol						1.1066	0.9464	1.2896		0.0508	0.1240	32.04	Option 2: A=7.8970, B=1474.080, C=229.130
Methyl ethyl ketone						0.8537	0.7394	0.9824		0.0585	0.1102	72.10	Option 2: A=6.9742, B=1209.600, C=216.000
Acetone						2.3582	2.0752	2.6724		0.0481	0.2502	58.08	Option 2: A=7.1170, B=1210.595, C=229.664
Water						0.1919	0.1612	0.2293		0.1575	0.0667	18.00	Option 1
Cyclohexanone						0.0411	0.0350	0.0482		0.0417	0.0038	98.20	Option 2: A=7.8492, B=2137.192, C=273.160
Ethyl acrylate						0.3753	0.3251	0.4321		0.0404	0.0334	100.11	Option 2: A=7.9645, B=1897.011, C=273.160
Butanol-(1)						0.0383	0.0304	0.0480		0.0402	0.0034	74.12	Option 2: A=7.4768, B=1362.390, C=178.770
Methyl isobutyl ketone						0.1582	0.1329	0.1874		0.0365	0.0127	100.20	Option 2: A=6.6720, B=1168.400, C=191.900
Chloroform						1.9471	1.7048	2.2164		0.0040	0.0172	119.39	Option 2: A=6.4930, B=929.440, C=196.030
Benzene						0.9248	0.8057	1.0583		0.0078	0.0159	78.11	Option 2: A=6.9050, B=1211.033, C=220.790
Formaldehyde						14.7000	14.7000	14.7000		0.0045	0.1459	30.02	Option 1
Hydrazine						0.0991	0.0825	0.1195		0.0017	0.0004	32.05	Option 1
Nitropropane(2-)						0.1532	0.1312	0.1751		0.0143	0.0048	89.09	Option 1
Acetonitrile						0.8929	0.7775	1.0224		0.0035	0.0069	41.05	Option 2: A=7.1190, B=1314.400, C=230.000
Carbon disulfide						3.9755	3.5542	4.4364		0.0020	0.0175	76.13	Option 2: A=6.9420, B=1169.110, C=241.590
Dimethyl hydrazine (1,1)						1.4881	1.2900	1.7111		0.0015	0.0049	60.10	Option 2: A=7.4080, B=1305.910, C=225.530
Dimethylamine						14.7000	14.7000	14.7000		0.0020	0.0648	45.08	Option 1
Xylene (-o)						0.0525	0.0439	0.0626		0.0388	0.0045	106.17	Option 2: A=6.9980, B=1474.679, C=213.690

Appendix III-1
Attachment 6

Annual Emission Calculations

Standing Losses (lb):	5.5107
Vapor Space Volume (cu ft):	78.54
Vapor Density (lb/cu ft):	0.0044
Vapor Space Expansion Factor:	0.045101
Vented Vapor Saturation Factor:	0.972409

Tank Vapor Space Volume

Vapor Space Volume (cu ft):	78.54
Tank Diameter (ft):	10
Vapor Space Outage (ft):	1.00
Tank Shell Height (ft):	34
Average Liquid Height (ft):	33
Roof Outage (ft):	0.00

Roof Outage (Cone Roof)

Roof Outage (ft):	0.00
Roof Height (ft):	0.000
Roof Slope (ft/ft):	0.00000
Shell Radius (ft):	5

Vapor Density

Vapor Density (lb/cu ft):	0.0044
Vapor Molecular Weight (lb/lb-mole):	44.933135
Vapor Pressure at Daily Average Liquid	
Surface Temperature (psia):	0.535352
Daily Avg. Liquid Surface Temp.(deg. R):	511.42
Daily Average Ambient Temp. (deg. R):	509.97
Ideal Gas Constant R	
(psia cuft /(lb-mole-deg R)):	10.731
Liquid Bulk Temperature (deg. R):	509.99
Tank Paint Solar Absorptance (Shell):	0.17
Tank Paint Solar Absorptance (Roof):	0.17
Daily Total Solar Insolation	
Factor (Btu/sqftday):	1069.00

Vapor Space Expansion Factor

Vapor Space Expansion Factor:	0.045101
Daily Vapor Temperature Range (deg.R):	18.91
Daily Vapor Pressure Range (psia):	0.115095
Breather Vent Press. Setting Range(psia):	0.00
Vapor Pressure at Daily Average Liquid	
Surface Temperature (psia):	0.535352
Vapor Pressure at Daily Minimum Liquid	
Surface Temperature (psia):	0.481849
Vapor Pressure at Daily Maximum Liquid	
Surface Temperature (psia):	0.596943
Daily Avg. Liquid Surface Temp. (deg R):	511.42
Daily Min. Liquid Surface Temp. (deg R):	506.69
Daily Max. Liquid Surface Temp. (deg R):	516.15
Daily Ambient Temp. Range (deg.R):	19.20

Annual Emission Calculations
Vented Vapor Saturation Factor
  Vented Vapor Saturation Factor: 0.972409
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.535352
  Vapor Space Outage (ft):   1.00

Withdrawal Losses (lb):   1738.5739
  Vapor Molecular Weight (lb/lb-mole): 44.933135
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.535352
  Annual Net Throughput (gal/yr):   14617282
  Turnover Factor: 0.2077
  Maximum Liquid Volume (cuft):   2670
  Maximum Liquid Height (ft):   34
  Tank Diameter (ft):   10
  Working Loss Product Factor: 1.00

Total Losses (lb):   1744.08

Annual Emissions Report

Liquid Contents	Losses (lbs.): Standing	Withdrawal	Total
	5.51	1738.57	1744.08
Octane (-n)	0.41	130.70	131.12
Cresol (-o)	0.00	0.44	0.44
Toluene	0.21	64.88	65.09
Methyl alcohol	0.68	215.58	216.26
Methyl ethyl ketone	0.61	191.51	192.12
Acetone	1.38	434.97	436.34
Water	0.37	115.92	116.29
Cyclohexanone	0.02	6.57	6.59
Ethyl acrylate	0.18	58.14	58.33
Butanol-(1)	0.02	5.90	5.92
Methyl isobutyl ketone	0.07	22.14	22.21
Chloroform	0.09	29.87	29.96
Benzene	.0.09	27.66	27.75
Formaldehyde	0.80	253.67	254.47
Hydrazine	0.00	0.65	0.65
Nitropropane(2-)	0.03	8.40	8.43
Acetonitrile	0.04	11.98	12.02
Carbon disulfide	0.10	30.49	30.59
Dimethyl hydrazine (1,1)	0.03	8.56	8.59
Dimethylamine	0.36	112.74	113.10
Xylene (-o)	0.02	7.82	7.84
Total:	5.51	1738.57	1744.08

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┌─────────────────────────────────────────────────────────────────────────┐
│                    TANKS PROGRAM 2.0                      10/16/95        │
│              EMISSIONS REPORT - DETAIL FORMAT             PAGE 1          │
│        TANK IDENTIFICATION AND PHYSICAL CHARACTERISTICS                   │
└─────────────────────────────────────────────────────────────────────────┘
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Identification
   Identification No.:   P/O
   City: Pittsburgh
   State: PA
   Company: WTI
   Type of Tank: Vertical Fixed Roof

Tank Dimensions
   Shell Height (ft):   8
   Diameter (ft):   8
   Liquid Height (ft):   8
   Avg. Liquid Height (ft):   7
   Volume (gallons):   3008
   Turnovers: 4906
   Net Throughput (gal/yr):   14652507

Paint Characteristics
   Shell Color/Shade: White/White
   Shell Condition: Good
   Roof Color/Shade: White/White
   Roof Condition: Good

Roof Characteristics
   Type: Cone
   Height (ft):   0.00
   Radius (ft) (Dome Roof):   0.00
   Slope (ft/ft) (Cone Roof):   0.0000

Breather Vent Settings
   Vacuum Setting (psig):   0.00
   Pressure Setting (psig):   0.00

Meteorological Data Used in Emission Calculations: Pittsburgh, Pennsylvania

Mixture/Component	Month	Daily Liquid Temperatures Avg.	Min.	Surf. (deg F) Max.	Liquid Bulk Temp. (deg F)	Vapor Pressures (psia) Avg.	Min.	Max.	Vapor Mol. Weight	Liquid Mass Fract.	Vapor Mass Fract.	Mol. Weight	Basis for Vapor Pressure Calculations
	All	51.75	47.02	56.48	50.32	0.4227	0.3685	0.4850	49.815				
Acetone						2.3582	2.0752	2.6724		0.0486	0.2904	58.08	Option 2: A=7.1170, B=1210.595, C=229.664
Acetonitrile						0.8929	0.7775	1.0224		0.0035	0.0079	41.05	Option 2: A=7.1190, B=1314.400, C=230.000
Benzene						0.9248	0.8057	1.0583		0.0078	0.0183	78.11	Option 2: A=6.9050, B=1211.033, C=220.790
Butanol-(1)						0.0383	0.0304	0.0480		0.0406	0.0039	74.12	Option 2: A=7.4768, B=1362.390, C=178.770
Chloroform						1.9471	1.7048	2.2164		0.0040	0.0197	119.39	Option 2: A=6.4930, B=929.440, C=196.030
Cresol (-o)						0.0011	0.0008	0.0015		0.1030	0.0003	108.14	Option 2: A=6.9110, B=1435.500, C=165.160
Cyclohexanone						0.0411	0.0350	0.0482		0.0422	0.0044	98.20	Option 2: A=7.8492, B=2137.192, C=273.160
Dichloroethane (1,1)						2.3582	2.0759	2.6693		0.0016	0.0096	98.97	Option 1
Dimethylamine						14.7000	14.7000	14.7000		0.0020	0.0745	45.08	Option 1
Ethyl acrylate						0.3753	0.3251	0.4321		0.0408	0.0388	100.11	Option 2: A=7.9645, B=1897.011, C=273.160
Methyl alcohol						1.1066	0.9464	1.2896		0.0513	0.1439	32.04	Option 2: A=7.8970, B=1474.080, C=229.130
Methyl ethyl ketone						0.8537	0.7394	0.9824		0.0592	0.1281	72.10	Option 2: A=6.9742, B=1209.600, C=216.000
Methyl isobutyl ketone						0.1582	0.1329	0.1874		0.0369	0.0148	100.20	Option 2: A=6.6720, B=1168.400, C=191.900
Octane (-n)						0.1228	0.1054	0.1426		0.2807	0.0873	114.23	Option 1
Toluene						0.2540	0.2176	0.2956		0.0674	0.0434	92.13	Option 2: A=6.9540, B=1344.800, C=219.480
Trichloroethane (1,1,1)						1.3182	1.1548	1.5015		0.0074	0.0247	133.42	Option 2: A=8.6430, B=2136.600, C=302.800
Trichloroethylene						0.6356	0.5469	0.7360		0.0045	0.0072	131.40	Option 2: A=6.5180, B=1018.600, C=192.700
Water						0.1919	0.1612	0.2293		0.1593	0.0775	18.00	Option 1
Xylene (-o)						0.0525	0.0439	0.0626		0.0392	0.0052	106.17	Option 2: A=6.9980, B=1474.679, C=213.690

Appendix III-1
Attachment 6

External Release Draft
Do Not Cite or Quote

Annual Emission Calculations

```
Standing Losses (lb):                          3.1075
  Vapor Space Volume (cu ft):                   50.27
  Vapor Density (lb/cu ft):                    0.0038
  Vapor Space Expansion Factor:              0.045138
  Vented Vapor Saturation Factor:            0.978090

Tank Vapor Space Volume
  Vapor Space Volume (cu ft):                   50.27
  Tank Diameter (ft):                               8
  Vapor Space Outage (ft):                       1.00
  Tank Shell Height (ft):                           8
  Average Liquid Height (ft):                       7
  Roof Outage (ft):                              0.00

Roof Outage (Cone Roof)
  Roof Outage (ft):                              0.00
  Roof Height (ft):                             0.000
  Roof Slope (ft/ft):                         0.00000
  Shell Radius (ft):                                4

Vapor Density
  Vapor Density (lb/cu ft):                    0.0038
  Vapor Molecular Weight (lb/lb-mole):      49.814730
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):                0.422662
  Daily Avg. Liquid Surface Temp.(deg. R):     511.42
  Daily Average Ambient Temp. (deg. R):        509.97
  Ideal Gas Constant R
    (psia cuft /(lb-mole-deg R)):              10.731
  Liquid Bulk Temperature (deg. R):            509.99
  Tank Paint Solar Absorptance (Shell):          0.17
  Tank Paint Solar Absorptance (Roof):           0.17
  Daily Total Solar Insolation
  Factor (Btu/sqftday):                       1069.00

Vapor Space Expansion Factor
  Vapor Space Expansion Factor:              0.045138
  Daily Vapor Temperature Range (deg.R):        18.91
  Daily Vapor Pressure Range (psia):         0.116535
  Breather Vent Press. Setting Range(psia):      0.00
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):                0.422662
  Vapor Pressure at Daily Minimum Liquid
  Surface Temperature (psia):                0.368506
  Vapor Pressure at Daily Maximum Liquid
  Surface Temperature (psia):                0.485042
  Daily Avg. Liquid Surface Temp. (deg R):     511.42
  Daily Min. Liquid Surface Temp. (deg R):     506.69
  Daily Max. Liquid Surface Temp. (deg R):     516.15
  Daily Ambient Temp. Range (deg.R):            19.20
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Appendix III-1
Attachment 6

8

Annual Emission Calculations
Vented Vapor Saturation Factor
  Vented Vapor Saturation Factor: 0.978090
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Vapor Space Outage (ft):   1.00

Withdrawal Losses (lb):   1269.4712
  Vapor Molecular Weight (lb/lb-mole):   49.814730
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Annual Net Throughput (gal/yr):   14652507
  Turnover Factor: 0.1728
  Maximum Liquid Volume (cuft):   402
  Maximum Liquid Height (ft):   8
  Tank Diameter (ft):   8
  Working Loss Product Factor: 1.00

Total Losses (lb):   1272.58

Annual Emissions Report

| Liquid Contents | Losses (lbs.): | | |
	Standing	Withdrawal	Total
	3.11	1269.47	1272.58
Acetone	0.90	368.70	369.60
Acetonitrile	0.02	10.05	10.08
Benzene	0.06	23.21	23.26
Butanol-(1)	0.01	5.00	5.01
Chloroform	0.06	25.06	25.12
Cresol (-o)	0.00	0.37	0.37
Cyclohexanone	0.01	5.58	5.59
Dichloroethane (1,1)	0.03	12.14	12.17
Dimethylamine	0.23	94.58	94.81
Ethyl acrylate	0.12	49.26	49.38
Methyl alcohol	0.45	182.63	183.08
Methyl ethyl ketone	0.40	162.59	162.98
Methyl isobutyl ketone	0.05	18.78	18.82
Octane (-n)	0.27	110.87	111.15
Toluene	0.13	55.08	55.22
Trichloroethane (1,1,1)	0.08	31.38	31.46
Trichloroethylene	0.02	9.20	9.22
Water	0.24	98.36	98.60
Xylene (-o)	0.02	6.62	6.64
Total:	3.11	1269.47	1272.58

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┌──────────────────────────────────────────────────────────────────────────────────┐
│                    TANKS PROGRAM 2.0                         10/16/95              │
│              EMISSIONS REPORT - DETAIL FORMAT                PAGE 1                │
│          TANK IDENTIFICATION AND PHYSICAL CHARACTERISTICS                          │
└──────────────────────────────────────────────────────────────────────────────────┘
```

Identification
    Identification No.:   Rec
    City: Pittsburgh
    State: PA
    Company: WTI
    Type of Tank: Vertical Fixed Roof

Tank Dimensions
    Shell Height (ft):   19
    Diameter (ft):   8
    Liquid Height (ft):   19
    Avg. Liquid Height (ft):   18
    Volume (gallons):   7145
    Turnovers: 2065
    Net Throughput (gal/yr):   14652507

Paint Characteristics
    Shell Color/Shade: White/White
    Shell Condition: Good
    Roof Color/Shade: White/White·
    Roof Condition: Good

Roof Characteristics
    Type: Cone
    Height (ft):   0.00
    Radius (ft) (Dome Roof):   0.00
    Slope (ft/ft) (Cone Roof):   0.0000

Breather Vent Settings
    Vacuum Setting (psig):   0.00
    Pressure Setting (psig):   0.00

Meteorological Data Used in Emission Calculations: Pittsburgh, Pennsylvania

Mixture/Component	Month	Daily Liquid Temperatures Avg.	Min.	Surf. (deg F) Max.	Liquid Bulk Temp. (deg F)	Vapor Pressures Avg.	Min.	(psia) Max.	Vapor Mol. Weight	Liquid Mass Fract.	Vapor Mass Fract.	Mol. Weight	Basis for Vapor Pressure Calculations
	All	51.75	47.02	56.48	50.32	0.4227	0.3685	0.4850	49.815				
Acetone						2.3582	2.0752	2.6724		0.0486	0.2904	58.08	Option 2: A=7.1170, B=1210.595, C=229.664
Acetonitrile						0.8929	0.7775	1.0224		0.0035	0.0079	41.05	Option 2: A=7.1190, B=1314.400, C=230.000
Benzene						0.9248	0.8057	1.0583		0.0078	0.0183	78.11	Option 2: A=6.9050, B=1211.033, C=220.790
Butanol-(1)						0.0383	0.0304	0.0480		0.0406	0.0039	74.12	Option 2: A=7.4768, B=1362.390, C=178.770
Chloroform						1.9471	1.7048	2.2164		0.0040	0.0197	119.39	Option 2: A=6.4930, B=929.440, C=196.030
Cresol (-o)						0.0011	0.0008	0.0015		0.1030	0.0003	108.14	Option 2: A=6.9110, B=1435.500, C=165.160
Cyclohexanone						0.0411	0.0350	0.0482		0.0422	0.0044	98.20	Option 2: A=7.8492, B=2137.192, C=273.160
Dichloroethane (1,1)						2.3582	2.0759	2.6693		0.0016	0.0096	98.97	Option 1
Dimethylamine						14.7000	14.7000	14.7000		0.0020	0.0745	45.08	Option 1
Ethyl acrylate						0.3753	0.3251	0.4321		0.0408	0.0388	100.11	Option 2: A=7.9645, B=1897.011, C=273.160
Methyl alcohol						1.1066	0.9464	1.2896		0.0513	0.1439	32.04	Option 2: A=7.8970, B=1474.080, C=229.130
Methyl ethyl ketone						0.8537	0.7394	0.9824		0.0592	0.1281	72.10	Option 2: A=6.9742, B=1209.600, C=216.000
Methyl isobutyl ketone						0.1582	0.1329	0.1874		0.0369	0.0148	100.20	Option 2: A=6.6720, B=1168.400, C=191.900
Octane (-n)						0.1228	0.1054	0.1426		0.2807	0.0873	114.23	Option 1
Toluene						0.2540	0.2176	0.2956		0.0674	0.0434	92.13	Option 2: A=6.9540, B=1344.800, C=219.480
Trichloroethane (1,1,1)						1.3182	1.1548	1.5015		0.0074	0.0247	133.42	Option 2: A=8.6430, B=2136.600, C=302.800
Trichloroethylene						0.6356	0.5469	0.7360		0.0045	0.0072	131.40	Option 2: A=6.5180, B=1018.600, C=192.700
Water						0.1919	0.1612	0.2293		0.1593	0.0775	18.00	Option 1
Xylene (-o)						0.0525	0.0439	0.0626		0.0392	0.0052	106.17	Option 2: A=6.9980, B=1474.679, C=213.690

Annual Emission Calculations

Standing Losses (lb):   3.1075
  Vapor Space Volume (cu ft):   50.27
  Vapor Density (lb/cu ft):   0.0038
  Vapor Space Expansion Factor: 0.045138
  Vented Vapor Saturation Factor: 0.978090

Tank Vapor Space Volume
  Vapor Space Volume (cu ft):   50.27
  Tank Diameter (ft):   8
  Vapor Space Outage (ft):   1.00
  Tank Shell Height (ft):   19
  Average Liquid Height (ft):   18
  Roof Outage (ft):   0.00

Roof Outage (Cone Roof)
  Roof Outage (ft):   0.00
  Roof Height (ft):   0.000
  Roof Slope (ft/ft):   0.00000
  Shell Radius (ft):   4

Vapor Density
  Vapor Density (lb/cu ft):   0.0038
  Vapor Molecular Weight (lb/lb-mole):   49.814730
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Daily Avg. Liquid Surface Temp.(deg. R):   511.42
  Daily Average Ambient Temp. (deg. R):   509.97
  Ideal Gas Constant R
   (psia cuft /(lb-mole-deg R)):   10.731
  Liquid Bulk Temperature (deg. R):   509.99
  Tank Paint Solar Absorptance (Shell):   0.17
  Tank Paint Solar Absorptance (Roof):   0.17
  Daily Total Solar Insolation
  Factor (Btu/sqftday):   1069.00

Vapor Space Expansion Factor
  Vapor Space Expansion Factor: 0.045138
  Daily Vapor Temperature Range (deg.R):   18.91
  Daily Vapor Pressure Range (psia):   0.116535
  Breather Vent Press. Setting Range(psia):   0.00
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Vapor Pressure at Daily Minimum Liquid
  Surface Temperature (psia):   0.368506
  Vapor Pressure at Daily Maximum Liquid
  Surface Temperature (psia):   0.485042
  Daily Avg. Liquid Surface Temp. (deg R):   511.42
  Daily Min. Liquid Surface Temp. (deg R):   506.69
  Daily Max. Liquid Surface Temp. (deg R):   516.15
  Daily Ambient Temp. Range (deg.R):   19.20

Appendix III-1
Attachment 6   13

External Release Draft
Do Not Cite or Quote

Annual Emission Calculations
Vented Vapor Saturation Factor
  Vented Vapor Saturation Factor: 0.978090
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Vapor Space Outage (ft):   1.00

Withdrawal Losses (lb):   1331.6814
  Vapor Molecular Weight (lb/lb-mole): 49.814730
  Vapor Pressure at Daily Average Liquid
  Surface Temperature (psia):   0.422662
  Annual Net Throughput (gal/yr):   14652507
  Turnover Factor: 0.1813
  Maximum Liquid Volume (cuft):   955
  Maximum Liquid Height (ft):   19
  Tank Diameter (ft):   8
  Working Loss Product Factor: 1.00

Total Losses (lb):   1334.79

Annual Emissions Report

Liquid Contents	Losses (lbs.): Standing	Withdrawal	Total
	3.11	1331.68	1334.79
Acetone	0.90	386.77	387.67
Acetonitrile	0.02	10.55	10.57
Benzene	0.06	24.34	24.40
Butanol-(1)	0.01	5.24	5.26
Chloroform	0.06	26.28	26.34
Cresol (-o)	0.00	0.39	0.39
Cyclohexanone	0.01	5.85	5.87
Dichloroethane (1,1)	0.03	12.73	12.76
Dimethylamine	0.23	99.22	99.45
Ethyl acrylate	0.12	51.67	51.80
Methyl alcohol	0.45	191.58	192.03
Methyl ethyl ketone	0.40	170.55	170.95
Methyl isobutyl ketone	0.05	19.70	19.74
Octane (-n)	0.27	116.31	116.58
Toluene	0.13	57.78	57.92
Trichloroethane (1,1,1)	0.08	32.92	33.00
Trichloroethylene	0.02	9.65	9.68
Water	0.24	103.18	103.42
Xylene (-o)	0.02	6.95	6.97
Total:	3.11	1331.68	1334.79

APPENDIX III-2

APPENDIX III-2
Measured Dioxin/Furan Congener Emission Rates
August 1993 ECIS Performance Test

Dioxin/Furan Congener	Emission Rate (g/sec) -- August 1993 ECIS Performance Test				
	Run 1	Run 2	Run 3	Run 4	Run 5
2,3,7,8-TCDD	<2.32e-11	<2.18e-11	<3.07e-11	<3.72e-11	<3.18e-11
1,2,3,7,8-PeCDD	1.72e-10	1.65e-10	2.32e-10	1.65e-10	1.67e-10
1,2,3,4,7,8-HxCDD	2.10e-10	2.02e-10	3.72e-10	2.23e-10	2.37e-10
1,2,3,6,7,8-HxCDD	2.86e-10	3.40e-10	5.23e-10	2.92e-10	3.83e-10
1,2,3,7,8,9-HxCDD	2.10e-10	2.23e-10	4.26e-10	1.91e-10	2.21e-10
1,2,3,4,6,7,8-HpCDD	1.61e-09	1.54e-09	5.28e-09	1.01e-09	1.51e-09
OCDD	6.47e-09	5.84e-09	5.39e-08	3.24e-09	5.17e-09
2,3,7,8-TCDF	1.94e-10	1.38e-10	2.37e-10	1.01e-10	7.54e-11
1,2,3,7,8-PeCDF	8.08e-10	7.43e-10	8.08e-10	7.44e-10	8.08e-10
2,3,4,7,8-PeCDF	9.70e-10	1.06e-09	1.51e-09	1.28e-09	1.24e-09
1,2,3,4,7,8-HxCDF	2.48e-09	3.34e-09	5.12e-09	3.78e-09	3.77e-09
1,2,3,6,7,8-HxCDF	2.64e-09	3.02e-09	4.58e-09	3.14e-09	3.29e-09
2,3,4,6,7,8-HxCDF	2.96e-09	3.87e-09	5.39e-09	3.67e-09	4.15e-09
1,2,3,7,8,9-HxCDF	4.15e-10	7.96e-10	1.13e-09	6.91e-10	7.00e-10
1,2,3,4,6,7,8-HpCDF	1.24e-08	1.59e-08	5.93e-08	1.28e-08	1.45e-08
1,2,3,4,7,8,9-HpCDF	1.67e-09	2.28e-09	9.16e-09	1.81e-09	2.16e-09
OCDF	1.83e-08	2.39e-08	2.69e-07	1.70e-08	1.67e-08

APPENDIX III-2
Measured Dioxin/Furan Congener Emission Rates
February 1994 Trial Burn

Dioxin/Furan Congener	Emission Rate (g/sec) — February 1994 Trial Burn			
	Run 1	Run 2	Run 3	Run 4
2,3,7,8-TCDD	<2.86e-11	<3.98e-11	<2.28e-11	<2.31e-11
1,2,3,7,8-PeCDD	6.83e-11	6.48e-11	5.51e-11	5.95e-11
1,2,3,4,7,8-HxCDD	1.18e-10	9.44e-11	8.06e-11	7.27e-11
1,2,3,6,7,8-HxCDD	2.23e-10	1.75e-10	1.68e-10	1.78e-10
1,2,3,7,8,9-HxCDD	1.18e-10	1.01e-10	8.06e-11	8.59e-11
1,2,3,4,6,7,8-HpCDD	1.32e-09	1.01e-09	8.06e-10	8.59e-10
OCDD	4.04e-09	2.43e-09	2.22e-09	1.78e-09
2,3,7,8-TCDF	1.11e-10	1.15e-10	8.06e-11	1.52e-10
1,2,3,7,8-PeCDF	4.67e-10	3.98e-10	2.89e-10	3.23e-10
2,3,4,7,8-PeCDF	5.29e-10	4.86e-10	3.97e-10	4.49e-10
1,2,3,4,7,8-HxCDF	2.02e-09	1.62e-09	1.34e-09	1.39e-09
1,2,3,6,7,8-HxCDF	1.88e-09	1.55e-09	1.28e-09	1.26e-09
2,3,4,6,7,8-HxCDF	1.88e-09	1.69e-09	1.48e-09	1.39e-09
1,2,3,7,8,9-HxCDF	3.76e-10	3.44e-10	2.69e-10	2.84e-10
1,2,3,4,6,7,8-HpCDF	1.25e-08	1.01e-08	8.06e-09	7.93e-09
1,2,3,4,7,8,9-HpCDF	1.60e-09	1.28e-09	1.01e-09	8.59e-10
OCDF	1.46e-08	8.77e-09	7.39e-09	5.22e-09

APPENDIX III-2
Measured Dioxin/Furan Congener Emission Rates
February 1994 ECIS Performance Test

Dioxin/Furan Congener	Emission Rate (g/sec) — February 1994 ECIS Performance Test				
	Run 2	Run 3	Run 4	Run 5	Run 7
2,3,7,8-TCDD	<5.90e-11	<2.20e-11	<4.03e-11	<4.58e-11	<6.72e-11
1,2,3,7,8-PeCDD	1.27e-10	3.42e-11	9.12e-11	6.99e-11	1.36e-10
1,2,3,4,7,8-HxCDD	2.09e-10	7.36e-11	1.37e-10	9.02e-11	1.43e-10
1,2,3,6,7,8-HxCDD	4.25e-10	1.21e-10	2.05e-10	1.65e-10	2.27e-10
1,2,3,7,8,9-HxCDD	3.51e-10	6.07e-11	1.82e-10	8.27e-11	1.81e-10
1,2,3,4,6,7,8-HpCDD	5.75e-09	7.59e-10	2.13e-09	9.01e-10	1.21e-09
OCDD	2.61e-08	2.28e-09	7.60e-09	2.48e-09	3.17e-09
2,3,7,8-TCDF	2.31e-10	7.29e-11	1.22e-10	6.76e-11	2.27e-10
1,2,3,7,8-PeCDF	6.19e-10	2.43e-10	4.03e-10	3.38e-10	5.89e-10
2,3,4,7,8-PeCDF	6.79e-10	2.66e-10	3.87e-10	3.91e-10	5.51e-10
1,2,3,4,7,8-HxCDF	1.42e-09	9.11e-10	1.06e-09	1.28e-09	1.36e-09
1,2,3,6,7,8-HxCDF	1.42e-09	8.35e-10	1.06e-09	1.28e-09	1.28e-09
2,3,4,6,7,8-HxCDF	1.57e-09	9.11e-10	1.14e-09	1.50e-09	1.28e-09
1,2,3,7,8,9-HxCDF	4.63e-10	1.67e-10	2.58e-10	3.16e-10	2.79e-10
1,2,3,4,6,7,8-HpCDF	8.21e-09	5.16e-09	6.08e-09	8.27e-09	6.65e-09
1,2,3,4,7,8,9-HpCDF	1.12e-09	4.93e-10	6.46e-10	8.27e-10	6.19e-10
OCDF	7.31e-09	3.34e-09	4.03e-09	5.56e-09	3.32e-09

APPENDIX III-2
Measured Dioxin/Furan Congener Emission Rates
April 1994 ECIS Performance Test

Dioxin/Furan Congener	Emission Rate (g/sec) – April 1994 ECIS Performance Test				
	Run 1	Run 2	Run 3	Run 4	Run 5
2,3,7,8-TCDD	<6.27e-11	<3.56e-11	<3.79e-11	<4.23e-11	<3.37e-11
1,2,3,7,8-PeCDD	<4.01e-11	<4.17e-11	<4.12e-11	<5.26e-11	<4.64e-11
1,2,3,4,7,8-HxCDD	<6.56e-11	<7.78e-11	<6.13e-11	<8.13e-11	<7.18e-11
1,2,3,6,7,8-HxCDD	<1.17e-10	8.34e-11	1.06e-10	1.03e-10	9.39e-11
1,2,3,7,8,9-HxCDD	<1.02e-10	<6.12e-11	<5.29e-11	<7.04e-11	<5.30e-11
1,2,3,4,6,7,8-HpCDD	8.02e-10	9.45e-10	8.36e-10	5.42e-10	4.52e-10
OCDD	5.54e-09	7.78e-09	3.57e-09	2.06e-09	1.71e-09
2,3,7,8-TCDF	8.02e-11	5.34e-11	3.06e-11	4.12e-11	3.31e-11
1,2,3,7,8-PeCDF	1.60e-10	1.28e-10	1.11e-10	1.35e-10	1.27e-10
2,3,4,7,8-PeCDF	2.62e-10	1.72e-10	1.84e-10	2.17e-10	1.32e-10
1,2,3,4,7,8-HxCDF	6.34e-10	6.67e-10	6.69e-10	7.04e-10	6.63e-10
1,2,3,6,7,8-HxCDF	7.29e-10	6.67e-10	6.69e-10	7.04e-10	6.63e-10
2,3,4,6,7,8-HxCDF	7.29e-10	6.67e-10	7.24e-10	8.13e-10	4.64e-10
1,2,3,7,8,9-HxCDF	1.24e-10	1.39e-10	1.28e-10	1.52e-10	9.94e-11
1,2,3,4,6,7,8-HpCDF	7.29e-09	8.90e-09	6.69e-09	5.96e-09	4.69e-09
1,2,3,4,7,8,9-HpCDF	9.48e-10	9.45e-10	7.80e-10	5.96e-10	3.42e-10
OCDF	2.11e-08	2.22e-08	1.11e-08	7.04e-09	4.86e-09

APPENDIX III-2
Measured Dioxin/Furan Emission Rates
August 1994 ECIS Performance Test

Dioxin/Furan Congener	Emission Rate (g/sec) -- August 1994 ECIS Performance Test						
	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
2,3,7,8-TCDD	<2.16e-11	<5.22e-11	<3.33e-11	<2.75e-11	<4.08e-11	<4.49e-11	<3.43e-11
1,2,3,7,8-PeCDD	<4.21e-11	<4.49e-11	<4.55e-11	<3.65e-11	<5.31e-11	<2.59e-11	<4.72e-11
1,2,3,4,7,8-HxCDD	<1.02e-10	<6.18e-11	<1.05e-10	<6.73e-11	<6.71e-11	<8.63e-11	<1.07e-11
1,2,3,6,7,8-HxCDD	<8.53e-11	<5.22e-11	<8.32e-11	<8.41e-11	<5.59e-11	<6.90e-11	<8.42e-11
1,2,3,7,8,9-HxCDD	<9.10e-11	<5.51e-11	<8.87e-11	<5.61e-11	<6.15e-11	<7.48e-11	<8.99e-11
1,2,3,4,6,7,8-HpCDD	6.26e-10	2.58e-10	3.94e-10	3.08e-10	3.80e-10	4.77e-10	5.34e-10
OCDD	4.15e-09	6.18e-10	1.22e-09	6.73e-10	1.73e-09	1.55e-09	2.47e-09
2,3,7,8-TCDF	<5.29e-11	<3.93e-11	<3.33e-11	<5.05e-11	<3.69e-11	<5.12e-11	<4.27e-11
1,2,3,7,8-PeCDF	1.19e-10	<7.86e-11	8.88e-11	1.12e-10	1.01e-10	1.32e-10	1.29e-10
2,3,4,7,8-PeCDF	1.31e-10	8.99e-11	1.33e-10	1.68e-10	1.12e-10	1.67e-10	1.69e-10
1,2,3,4,7,8-HxCDF	3.81e-10	2.92e-10	3.72e-10	3.98e-10	3.97e-10	4.77e-10	5.28e-10
1,2,3,6,7,8-HxCDF	3.81e-10	2.70e-10	3.66e-10	3.93e-10	3.91e-10	4.66e-10	4.94e-10
2,3,4,6,7,8-HxCDF	4.38e-10	2.87e-10	4.05e-10	3.93e-10	4.02e-10	4.54e-10	4.66e-10
1,2,3,7,8,9-HxCDF	1.14e-10	<3.71e-11	8.32e-11	<5.55e-11	1.12e-10	1.21e-10	<7.86e-11
1,2,3,4,6,7,8-HpCDF	3.36e-09	1.85e-09	2.94e-09	2.36e-09	3.13e-09	3.05e-09	3.82e-09
1,2,3,4,7,8,9-HpCDF	5.57e-10	2.30e-10	3.05e-10	2.97e-10	4.08e-10	3.39e-10	4.66e-10
OCDF	5.52e-09	<8.99e-10	2.33e-09	<1.12e-09	3.80e-09	2.07e-09	<6.18e-09

APPENDIX III-3

	APPENDIX III-3 Products of Incomplete Combustion Analyzed for and Detected in the Trial Burns and Performance Tests	
Substance	**Compounds Detected in Stack Emissions**	**Compounds Analyzed for but Not Detected in Stack Emissions**
Acenaphthene		Feb-94
Acenaphthylene		Feb-94
Acetaldehyde		
Acetone	Feb-94	
Acetophenone		
Acrolein*		
Acrylonitrile		Mar-93
Anthracene		Feb-94, Aug-94
Benzaldehyde*		
Benzene	Mar-93, Feb-94, Aug-94	
Benzoic acid	Feb-94	
Benzotrichloride		
Benzo(a)anthracene		Feb-94, Aug-94
Benzo(a)pyrene		Feb-94, Aug-94
Benzo(b)fluoranthene		Feb-94, Aug-94
Benzo(e)pyrene*		
Benzo(g,h,i)perylene		Feb-94, Aug-94
Benzo(j)fluoranthene*		
Benzo(k)fluoranthene		Feb-94, Aug-94
Benzyl chloride*		
Biphenyl*		
Bis(2-chloroethoxy)methane		Feb-94
Bis(2-chloroethyl)ether		Feb-94
Bis(2-chloroisopropyl)ether		Feb-94
Bis(2-ethylhexyl)phthalate	Feb-94, Aug-94	
Bromodichloromethane	Feb-94, Aug-94	
Bromodichloromethane*		
Bromoethene*		
Bromoform	Feb-94	Aug-94
Bromomethane	Feb-94	Aug-94

APPENDIX III-3 Products of Incomplete Combustion Analyzed for and Detected in the Trial Burns and Performance Tests (continued)		
Substance	Compounds Detected in Stack Emissions	Compounds Analyzed for but Not Detected in Stack Emissions
Bromodiphenylether, p-		Feb-94
Butadiene, 1,3-*		
Butanone, 2- (MEK)	Aug-94	
Butylbenzylphthalate		Feb-94, Aug-94
Carbon disulfide	Feb-94, Aug-94	
Carbon tetrachloride	Aug-94	
Chlordane		Aug-94
Chloro-3-methylphenol, 4-		Feb-94
Chloroacetophenone, 2-*		
Chloroaniline, p-		Feb-94
Chlorobenzene		Aug-94
Chlorobenzilate		
Chloroethane		Feb-94, Aug-94
Chloroform	Mar-93, Feb-94, Aug-94	
Chloromethane	Feb-94	Aug-94
Chloronaphthalene, beta-		Feb-94
Chlorophenol, 2-		Aug-94
Chlorodiphenyl ether, 4-		Feb-94
Chloropropane, 2-*		
Chrysene		Feb-94, Aug-94
Cresol, m-		Aug-94
Cresol, o-		Aug-94
Cresol, p-		Aug-94
Crotonaldehyde		
Cumene		Aug-94
2,4-D		
4,4'-DDE		Aug-94
Dibenz(a,h)anthracene		Feb-94, Aug-94
Dibenzo(a,h)fluoranthene		Aug-94

APPENDIX III-3 Products of Incomplete Combustion Analyzed for and Detected in the Trial Burns and Performance Tests (continued)		
Substance	**Compounds Detected in Stack Emissions**	**Compounds Analyzed for but Not Detected in Stack Emissions**
Dibromo-3-chloropropane, 1,2-*		
Dibromochloromethane	Feb-94	
Dichloro-2-butene, cis-1,4-*		
Dichloro-2-butene, trans-1,4-*		
Dichlorobenzene, 1,2-	Feb-94	Mar-93, Aug-94
Dichlorobenzene, 1,3-		Mar-93, Feb-94, Aug-94
Dichlorobenzene, 1,4-	Feb-94	Mar-93, Aug-94
Dichlorobenzidine, 3,3'-		Mar-93, Feb-94
Dichlorobiphenyl	Aug-94	
Dichlorodifluoromethane		Aug-94
Dichloroethane, 1,1-		Feb-94, Aug-94
Dichloroethane, 1,2-		Mar-93, Feb-94, Aug-94
Dichloroethene, 1,1-		Feb-94, Aug-94
Dichloroethene, trans-1,2-		Feb-94, Aug-94
Dichlorofluoromethane*		
Dichlorophenol, 2,4-		Feb-94, Aug-94
Dichloropropane, 1,2-		Feb-94, Aug-94
Dichloropropene, cis-1,3-		Mar-93, Feb-94, Aug-94
Dichloropropene, trans-1,3-		Mar-93, Feb-94, Aug-94
Diethylphthalate	Feb-94, Aug-94	
Dimethoxybenzidine, 3,3'-		
Dimethylphenol, 2,4-		Feb-94, Aug-94
Dimethylphthalate		Feb-94, Aug-94
Di-n-butylphthalate	Feb-94, Aug-94	
Di-n-octyl phthalate		Feb-94, Aug-94
Dinitrotoluene, 2,6-		Feb-94, Aug-94
Dinitro-2-methylphenol, 4,6-		Feb-94, Aug-94
Dinitrobenzene, 1,2-*		
Dinitrobenzene, 1,3-*		

APPENDIX III-3
Products of Incomplete Combustion Analyzed for
and Detected in the Trial Burns and Performance Tests
(continued)

Substance	Compounds Detected in Stack Emissions	Compounds Analyzed for but Not Detected in Stack Emissions
Dinitrobenzene, 1,4-*		
Dinitrophenol, 2,4-		Feb-94, Aug-94
Dinitrotoluene, 2,4-		Feb-94, Aug-94
Dioxane, 1,4-		
Ethyl methacrylate		Aug-94
Ethylbenzene	Feb-94, Aug-94	
Ethylene dibromide		
Ethylene oxide		
Ethylene thiourea		
Fluoranthene		Feb-94, Aug-94
Fluorene		Feb-94
Formaldehyde		
Furfural		Aug-94
Heptachlor		Aug-94
Heptachlorobiphenyl		Aug-94
Hexachlorobenzene		Feb-94, Aug-94
Hexachlorobiphenyl		Aug-94
Hexachlorobutadiene		Feb-94
Hexachlorocyclohexane, alpha-*		
Hexachlorocyclohexane, beta-*		
Hexachlorocyclohexane, gamma- (a.k.a. Lindane)		
Hexachlorocyclopentadiene		Feb-94, Aug-94
Hexachloroethane		Mar-93, Feb-94, Aug-94
Hexachlorophene		
Hexane, n-*		
Hexanone, 2-		Feb-94
Hexanone, 3-*		
Indeno(1,2,3-cd)pyrene		Feb-94, Aug-94

APPENDIX III-3		
Products of Incomplete Combustion Analyzed for and Detected in the Trial Burns and Performance Tests (continued)		
Substance	Compounds Detected in Stack Emissions	Compounds Analyzed for but Not Detected in Stack Emissions
Isophorone		Feb-94
Maleic hydrazide		
Methoxychlor		Aug-94
Methylene bromide*		
Methylene chloride	Feb-94, Aug-94	Mar-93
Methylnaphthalene, 2-	Feb-94	
Methyl-tert-butyl ether		Aug-94
Methyl-2-Pentanone, 4-		Feb-94, Aug-94
Monochlorobiphenyl	Aug-94	
Naphthalene	Feb-94	Aug-94
Nitroaniline, 2-		Feb-94
Nitroaniline, 3-		Feb-94
Nitroaniline, 4-		Feb-94
Nitrobenzene		Feb-94, Aug-94
Nitrophenol, 2-		Feb-94
Nitrophenol, 4-		Feb-94, Aug-94
N-Nitroso-di-n-butylamine		Mar-93
N-Nitroso-di-n-propylamine		Feb-94
N-Nitrosodiphenylamine		Feb-94
Nonachlorobiphenyl		Aug-94
Octachlorobiphenyl		Aug-94
Pentachlorobenzene		
Pentachlorobiphenyl		Aug-94
Pentachloronitrobenzene		
Pentachlorophenol		Feb-94, Aug-94
Phenanthrene		Feb-94
Phenol		Feb-94, Aug-94
Phosgene*		
Propionaldehyde*		

APPENDIX III-3 Products of Incomplete Combustion Analyzed for and Detected in the Trial Burns and Performance Tests (continued)		
Substance	Compounds Detected in Stack Emissions	Compounds Analyzed for but Not Detected in Stack Emissions
Pyrene		Feb-94, Aug-94
Quinoline*		
Quinone*		
Safrole		
Styrene	Feb-94, Aug-94	
Tetrachlorobenzene, 1, 2, 4, 5-*		
Tetrachlorobiphenyl		Aug-94
Tetrachloroethane, 1,1,1,2-		Aug-94
Tetrachloroethane, 1,1,2,2-		Feb-94, Aug-94
Tetrachloroethene	Mar-93, Feb-94, Aug-94	
Tetrachlorophenol, 2,3,4,6-		
Toluene	Feb-94, Aug-94	
Toluidine, o-*		
Toluidine, p-*		
Trichloro-1,2,2-trifluoroethane, 1,1,2-		
Trichlorobenzene, 1,2,4-		Aug-94
Trichlorobiphenyl	Aug-94	
Trichloroethane, 1,1,1-	Feb-94	Aug-94
Trichloroethane, 1,1,2-	.	Feb-94, Aug-94
Trichloroethene	Aug-94	
Trichlorofluoromethane	Feb-94	Aug-94
Trichlorophenol, 2,4,5-		Feb-94, Aug-94
Trichlorophenol, 2,4,6-		Mar-93, Feb-94, Aug-94
Trichloropropane, 1,2,3-*		
Vinyl acetate		Feb-94
Vinyl chloride		Feb-94, Aug-94
Xylene, m-/p-	Feb-94, Aug-94	
Xylene, o-	Feb-94	Aug-94

APPENDIX III-3
Products of Incomplete Combustion Analyzed for
and Detected in the Trial Burns and Performance Tests
(continued)

Notes:

Mar 93 - March 1993 trial burn
Feb 94 - February 1994 trial burn
Aug 94 - August 1994 PIC testing

*   These compounds were not listed in the waste profile sheets or analyzed for in the stack emissions. Thus, incinerator stack emission rates are not developed for these compounds.

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