

FINAL

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K015

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EXECUTIVE SUMMARY

BDAT Treatment Standards for K015

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act as enacted by the Hazardous and Solid Waste Amendments on November 8, 1984, the Environmental Protection Agency (EPA) is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K015. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. These treatment standards become effective as of August 8, 1988.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K015 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization information that serves as a basis for determining whether treatment variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the waste upon which the treatment standards have been established.

The introductory section, which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and

discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information--the number and locations of facilities affected by land disposal restrictions for K015 waste, the waste-generating process, characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

According to 40 CFR 261.32, waste code K015 is generated by the organic chemicals industry and is listed as "still bottoms from the distillation of benzyl chloride." EPA has estimated that two facilities are potential generators of K015 waste.

The Agency is regulating five organic and two inorganic constituents in wastewater forms of K015. (For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Waste not meeting this definition must comply with the treatment

*The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by method 209C (Total Suspended Solids Dried at 103-105°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition.

standards for nonwastewaters.) The BDAT treatment standard of "no land disposal" for K015 nonwastewater is based on the performance of liquid injection incineration and the fact that the waste contained no measurable ash (the solid residue from incineration). The treatment standards for the BDAT list organic constituents in wastewater forms of K001 are based on performance data from liquid injection incineration. For the BDAT list metal constituents, the treatment standards for wastewater are based on performance data from chromium reduction and chemical precipitation.

The following table presents the treatment standards for K015 nonwastewater and wastewater. The BDAT treatment standard for K015 nonwastewater is "no land disposal" based on no measurable ash (solid residue) generated from liquid injection incineration. For BDAT list organic constituents in K015 wastewater, treatment standards reflect the total constituent concentration in the scrubber water from liquid injection incineration. For BDAT list metal constituents, the treatment standards in the wastewater reflect the total constituent concentration.

The units for the total constituent concentration are mg/l (parts per million on a weight-by-volume basis) for the wastewater. Note that if the concentrations of the regulated constituents in the waste, as generated, are lower than or equal to the treatment standards, then treatment is not required prior to land disposal.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix B of this background document.

BDAT Treatment Standards for K015

Constituent	Maximum for any single grab sample		
	Nonwastewater ^a		Wastewater
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
<u>Volatile Organics</u>			
Toluene			0.15
<u>Semivolatile Organics</u>			
Anthracene			1.0
Benzal chloride	No Land Disposal		0.28
Benzo(b and/or k)fluoranthene			0.29
Phenanthrene			0.27
<u>Metals</u>			
Chromium			0.32
Nickel			0.44

^aThe Agency is establishing a treatment standard of "No Land Disposal" for K015 nonwastewater based on no ash.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous

constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such

characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters.

Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In

addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and
5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment

levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to

treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic

constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the

toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.
2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:
 - Number and types of constituents treated;
 - Performance (concentration of the constituents in the treatment residuals); and
 - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment

standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
<u>Volatile organics</u>		
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
<u>Volatile organics (continued)</u>		
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoro- ethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4-Xylene	106-44-5
<u>Semivolatile organics</u>		
51.	Acenaphthylene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benzo(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAI reference no.	Constituent	CAS no.
<u>Semivolatile organics</u> (continued)		
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propyl nitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
<u>Semivolatile organics</u> (continued)		
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
<u>Semivolatile organics (continued)</u>		
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
<u>Metals</u>		
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
<u>Inorganics other than metals</u>		
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
<u>Organochlorine pesticides</u>		
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BOAT reference no.	Constituent	CAS no.
<u>Organochlorine pesticides (continued)</u>		
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxychlor	72-43-5
191.	Toxaphene	8001-35-2
<u>Phenoxyacetic acid herbicides</u>		
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
<u>Organophosphorous insecticides</u>		
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
<u>PCBs</u>		
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104-28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
<u>Dioxins and furans</u>		
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex

waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.
2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.
3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.
4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be present.

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based

on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.
3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.
2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.
3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.
4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards; then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the

specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.
3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a

separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the appropriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are

covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are

expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the

requirements of 40 CFR Part 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.
2. A statement of the petitioner's interest in the proposed action.
3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.
4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.
5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)
6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)
7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.
8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.
10. A description of the methodologies and equipment used to obtain representative samples.
11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.
12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are

appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

This section discusses the industry affected by the land disposal restrictions for K015 waste, describes the process that generates the waste, and presents available waste characterization data.

2.1 Industry Affected and Process Description

According to 40 CFR Part 261.32, waste identified as K015 is specifically generated by the organic chemicals industry and is listed as "still bottoms from the distillation of benzyl chloride." The Agency estimates that two facilities in the United States currently generate K015 waste. These facilities are located in New Jersey and Tennessee (EPA Regions II and IV, respectively). Benzyl chloride is used as a raw material or chemical intermediate in the production of benzyl phthalates, pharmaceuticals, quaternary ammonium salts, benzyl alcohol, and other compounds including esters, dyes, and solvents.

In the United States, benzyl chloride is currently produced by photochemical chlorination of toluene. A flow diagram of the production process is presented in Figure 2-1. Chlorine is fed into a heated reactor or series of reactors containing boiling toluene. The toluene and chlorine react to form benzyl chloride and hydrogen chloride gas. The hydrogen chloride gas is purged from the reactor(s), while the unreacted toluene and the remaining reaction products are sent to a distillation column where toluene is recovered. The product stream is further distilled, producing purified benzyl chloride. The still bottoms from this step are the listed waste K015.

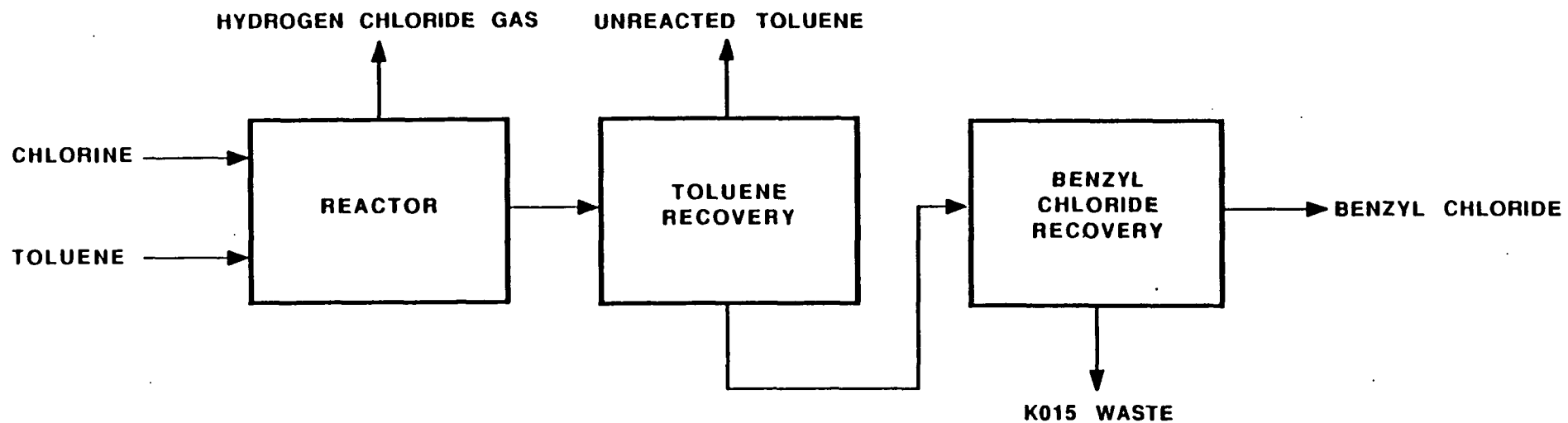


FIGURE 2-1. BENZYL CHLORIDE PRODUCTION BY THE CHLORINATION OF TOLUENE

2.2 Waste Characterization

K015 waste generally contains greater than 88 percent benzal chloride, less than 12 percent benzotrichloride and other chlorinated benzenes, less than 5 percent benzyl chloride, less than 1 percent toluene, less than 1 percent other BDAT constituents, and less than 1 percent water. Other industry-submitted information indicates the following approximations: 80 to 90 percent benzal chloride, 3 to 10 percent benzyl chloride, 8 to 12 percent other chlorinated hydrocarbons (usually toluene), and less than 1 percent water. These approximations are listed in Table 2-1. The constituent concentrations are estimates based on chemical analyses and information generated by earlier EPA studies. Results of the chemical analyses used in estimating the composition of K015 waste from tests conducted by the Agency are presented in Table 2-2. These tests determined that the heating value was 10,000 Btu/lb, the carbon content and sulfur content were approximately 51 and 0.22 percent, respectively, and the waste had a low (0.09 percent) ash content.

Table 2-1 Major Constituent Composition for K015 Waste

Constituent	<u>Range of concentrations (percent)</u>	
	(1)	(2)
Benzal chloride	>88	80-90
Benzotrichloride and other chlorinated benzenes	<12	8-12
Benzyl chloride	<5	3-10
Toluene	<1	8-12
Other BDAT constituents	<1	-
Water	<1	<1

Source References: (1) USEPA 1987a, p.2-2.
(2) USEPA 1987b.

Table 2-2 BDAT Constituent Composition and Other Data

Parameter	Untreated waste concentration (mg/kg)
<u>BDAT volatile organics (mg/kg)</u>	
Toluene	<10
<u>BDAT semivolatile organics (mg/kg)</u>	
Anthracene	<5,000
Benzal chloride	880,000
Benzo(b and/or k)fluoranthene	<5,000
Phenanthrene	<5,000
<u>Other parameters</u>	
Ash content (%)	0.01 - 0.29 (0.09 average)
Heating value (Btu/lb)	10,000
Carbon content (%)	51.0 - 51.3 (51.1 average)
Dry loss (%)	96.0 - 99.0 (97.2 average)
Sulfur content (%)	0.03 - 0.32 (0.22 average)
Water content (%)	<1

Reference: USEPA 1987a, p. 6-3.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section describes the applicable and demonstrated treatment technologies for K015 waste. Detailed discussions are provided for those technologies that have been demonstrated on a commercial basis.

3.1 Applicable Treatment Technologies

The Agency identified applicable treatment technologies based on available waste composition data, literature sources, engineering site visits, and industry-submitted data. As shown in Section 2, K015 waste primarily contains high concentrations of organic compounds and has a low suspended solids concentration and a low water content. The technologies considered to be applicable for K015 waste are those that destroy or reduce the concentration of organic constituents in the waste. The Agency has identified two treatment technologies as applicable for K015 waste--incineration and fuel substitution--and has identified chromium reduction and chemical precipitation as applicable technologies for metals reduction in incineration scrubber water.

Incineration destroys the organic constituents in the waste; the technology also results in the formation of residuals (i.e., ash and scrubber water) with reduced concentrations of organic constituents. As shown in Section 2, K015 waste has a very low (0.09 percent) ash content, so no ash is expected to be generated from incineration. The wastewater (scrubber water) residual generated from incineration may contain treatable concentrations of BDAT list metals if they are present in the untreated waste. Fuel substitution, similar to incineration, destroys

the organic constituents in the waste; however, fuel substitution also derives fuel value from the waste.

The Agency believes that solvent extraction may be applicable to K015 waste; however, EPA has not identified any facilities using solvent extraction on K015 or a similar waste. The Agency does not currently have sufficient information on waste parameters that affect treatment selection for solvent extraction to suggest that this technology is applicable for wastes similar to K015. Accordingly, EPA does not consider solvent extraction to be an applicable technology.

For treatment of BDAT list metals in the wastewater from incineration of K015, EPA has identified chromium reduction followed by chemical precipitation as applicable technologies. These technologies are commonly practiced for metal-containing wastewaters. Chromium reduction reduces hexavalent chromium to the less soluble trivalent form; chemical precipitation removes dissolved metals from solution.

3.2 Demonstrated Treatment Technologies

EPA has identified incineration and fuel substitution as the demonstrated treatment technologies for K015 waste, as well as chromium reduction and chemical precipitation for removal of metals from incineration scrubber water. The Agency has identified three facilities using incineration for treatment of BDAT list organics in K015. Incineration is a widely used full-scale treatment technology for wastes containing high concentrations of BDAT list organic constituents. The goal of incineration is to thermally destroy (oxidize) the organic

constituents of a waste. Typically, the types of incineration systems that are demonstrated on wastes include fluidized bed, rotary kiln, fixed hearth, and liquid injection. Liquid injection incineration systems are specifically designed to handle liquids with low concentrations of suspended solids such as K015. However, while rotary kilns and fluidized bed incinerators are generally designed to handle sludges and solids, these units often are used to incinerate liquids. The Agency believes that the performance of liquid injection incineration adequately represents the performance achievable by other incineration technologies (including fuel substitution) that are well designed and well operated. Section 3.2.1 describes incineration technologies in more detail.

The Agency considers fuel substitution to be demonstrated on K015 waste because it is demonstrated on other wastes having similar parameters affecting treatment selection. Fuel substitution is described in greater detail in Section 3.2.2.

For K015 wastewaters containing treatable concentrations of BDAT list metals resulting from incineration, the Agency has not identified any facilities using chromium reduction followed by chemical precipitation on the scrubber water generated by incineration of K015. However, the Agency believes that chromium reduction and chemical precipitation are demonstrated for K015 wastewaters because they are demonstrated on other wastewater streams containing BDAT list metals. Sections 3.2.3 and 3.2.4 describe chromium reduction and chemical precipitation.

3.2.1 Incineration

This section addresses the commonly used incineration technologies: liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and, finally, important design and operating parameters. As appropriate, the subsections are divided by type of incineration unit.

(1) Applicability and use of incineration.

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported, with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be

demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that air emissions from incinerating some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than those currently used.

(2) Underlying principles of operation.

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents will oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology is somewhat different from that for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed incineration, the purpose of the primary chamber is not only to volatilize the wastes but also to essentially combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of a fluidized bed incinerator than in that of a rotary kiln or fixed hearth incinerator because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of the incineration process.

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber, where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder

lined with refractory (i.e., heat-resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln, where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone (see Figure 3-3).

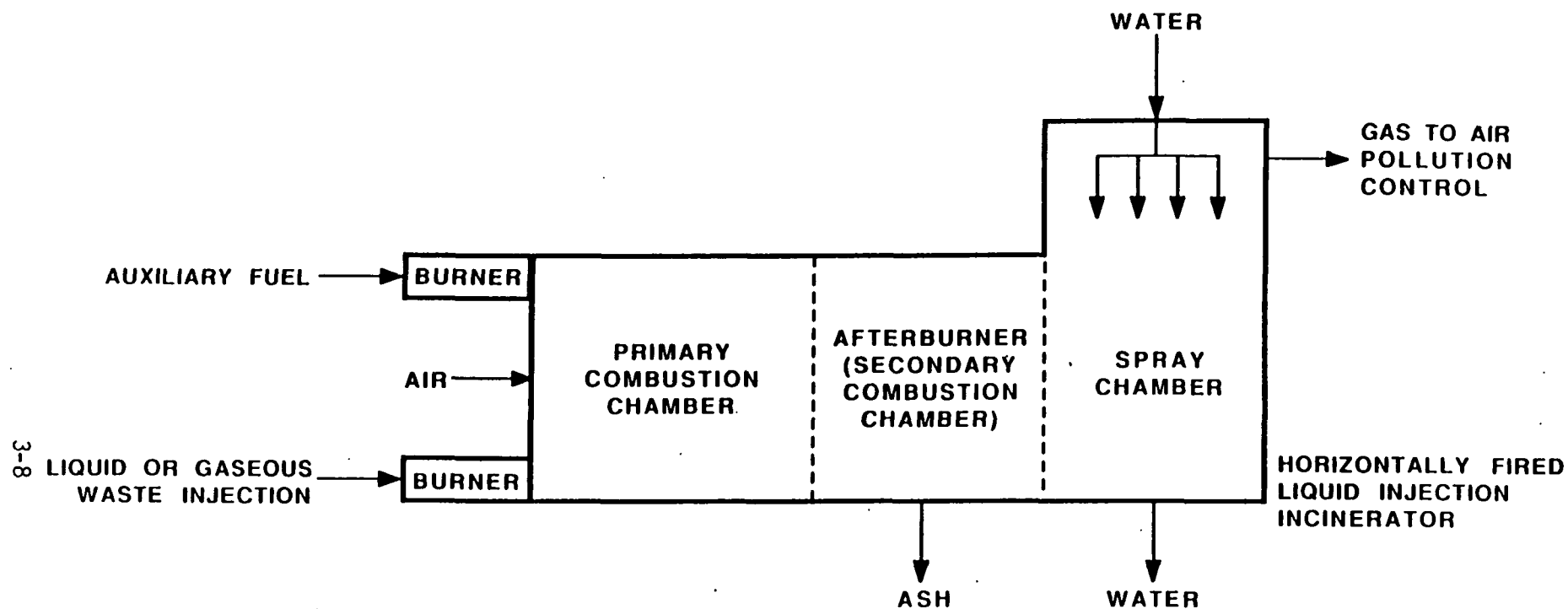


FIGURE 3-1
LIQUID INJECTION INCINERATOR

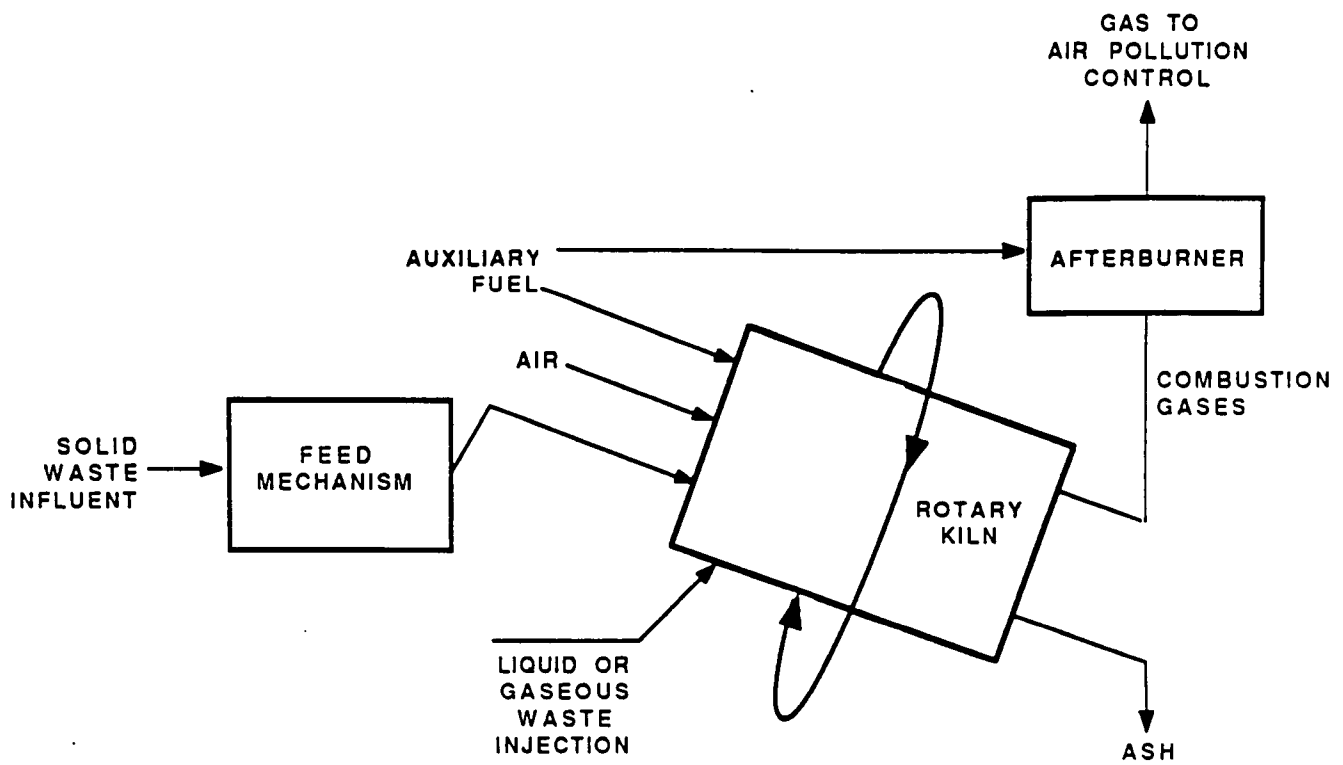


FIGURE 3-2
ROTARY KILN INCINERATOR

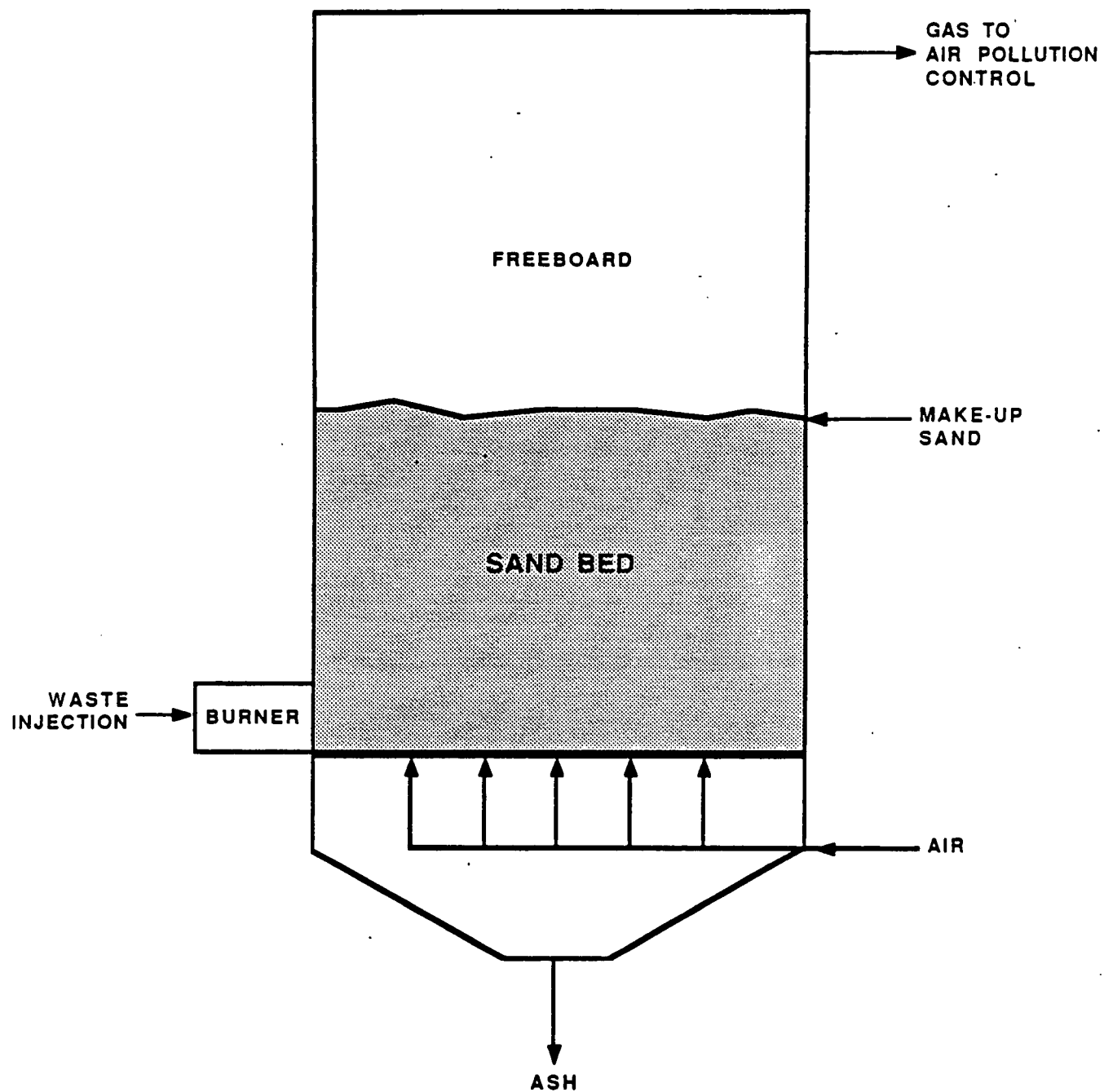


FIGURE 3-3
FLUIDIZED BED INCINERATOR

(d) Fixed hearth. Fixed hearth incineration, also called controlled air or starved air incineration, is another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove hydrochloric acid and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will exit either as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters of less than 1 micron and require high-efficiency collection devices to

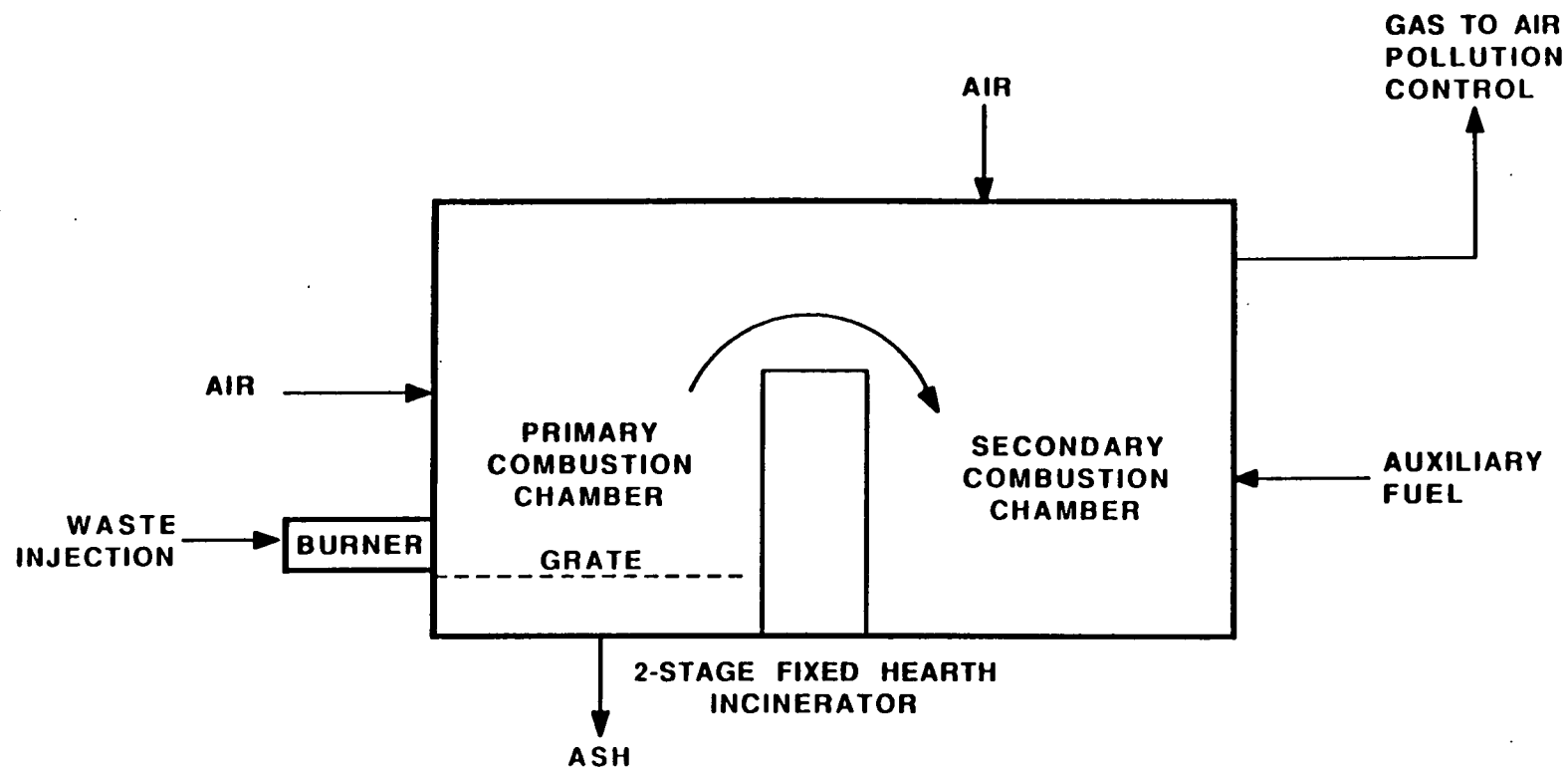


FIGURE 3-4
FIXED HEARTH INCINERATOR

minimize air emissions. In addition, scrubber systems provide an additional buffer against accidental releases of incompletely destroyed waste products, which result from poor combustion efficiency or combustion upsets, such as flameouts.

(4) Waste characteristics affecting performance.

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested wastes. This parameter is being used as a surrogate indicator of activation energy which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case. Other energy effects (e.g., vibrational effects, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state. Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data was rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess

volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than of the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of the incinerator than of the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as how it can be measured, is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and is referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described in Appendix C.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of the heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and the other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow

through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics.

Therefore, these parameters do not provide a better indication of the heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, removal of this constituent from the waste will depend on its volatility. EPA is using boiling point as a surrogate of volatility of the constituent. Compounds with lower boiling points have higher vapor pressures and therefore would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Design and operating parameters.

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency

will evaluate to assess whether these conditions are met are temperature, excess oxygen, and residence time. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposal restriction standards, EPA is concerned with these design parameters only when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned only with the waste characteristics that affect selection of the unit, not with the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, it is more likely that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation that senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to

know not only the exact location in the incinerator at which the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. It is important that the incinerator contain oxygen in excess of the stoichiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location at which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are

unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, one can calculate the volume of combustion gas. After both the Btu content and the expected combustion gas volume have been determined, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit is being operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether sufficient energy is likely to be provided to the waste to volatilize the waste constituents. For the

secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature is important, in that it provides an indirect measure of the energy input (i.e., Btu/hr) available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln, including

the length and diameter of the kiln, the waste feed rate, and the rate of rotation. .

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as the RPM value increases, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously in the section "Underlying principles of operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas (if halogens are present). The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were included in the discussion of the rotary kiln and will not be discussed here. The last, bed pressure differential, is important in that it provides an indication of the amount of turbulence and therefore indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase.

The pressure drop through the bed should be continuously monitored and recorded to ensure that the designed value is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln with the exception that rate of rotation (i.e., RPM) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under "Rotary kiln"; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those previously discussed under "Liquid injection."

3.2.2 Fuel Substitution

Fuel substitution involves using hazardous waste as a fuel in industrial furnaces or in boilers for generation of steam. The hazardous waste may be blended with other nonhazardous wastes (e.g., municipal sludge) and/or fossil fuels.

(1) Applicability and use of fuel substitution. Fuel substitution has been used with industrial waste solvents, refinery wastes, synthetic fibers/petrochemical wastes, and waste oils. It can also be used when combusting other waste types produced during the manufacture of pharmaceuticals, pulp and paper, and pesticides. These wastes can be handled in a solid, liquid, or gaseous form.

The most common types of units in which waste fuels are burned are industrial furnaces and industrial boilers. Industrial furnaces include a diverse variety of industrial processes that produce heat and/or

products by burning fuels. They include blast furnaces, smelters, and coke ovens. Industrial boilers are units wherein fuel is used to produce steam for process and plant use. Industrial boilers typically use coal, oil, or gas as the primary fuel source.

A number of parameters affect the selection of fuel substitution. These parameters are as follows:

- Halogen content of the waste;
- Inorganic solids content (ash content) of the waste, particularly heavy metals;
- Heating value of the waste;
- Viscosity of the waste (for liquids);
- Filterable solids concentration (for liquids); and
- Sulfur content.

If halogenated organics are burned, halogenated acids and free halogen are among the products of combustion. These released corrosive gases may require subsequent treatment prior to venting to the atmosphere. Also, halogens and halogenated acids formed during combustion are likely to severely corrode boiler tubes and other process equipment. For this reason, halogenated wastes are blended into fuels only at very low concentrations to minimize such problems. High chlorine content can also lead to the incidental production (at very low concentrations) of other hazardous compounds such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and chlorinated phenols.

High inorganic solids content (i.e., ash content) of wastes may cause two problems: (1) scaling in the boiler and (2) particulate air emissions. Scaling results from deposition of inorganic solids on the walls of the boiler. Particulate emissions are produced by noncombustible inorganic constituents that flow out of the boiler with the gaseous combustion products. Because of these problems, wastes with significant concentrations of inorganic materials are not usually handled in boilers unless the boilers have an air pollution control system.

Industrial furnaces vary in their tolerance to inorganic constituents. Heavy metal concentrations, found in both halogenated and nonhalogenated wastes used as fuel, can cause environmental concern because they may be emitted in the gaseous emissions from the combustion process, in the ash residues, or in any produced solids. The partitioning of the heavy metals to these residual streams primarily depends on the volatility of the metal, waste matrix, and furnace design.

The heating value of the waste must be sufficiently high (either alone or in combination with other fuels) to maintain combustion temperatures consistent with efficient waste destruction and operation of the boiler or furnace. For many applications, only supplemental fuels having minimum heating values of 4,400 to 5,600 kcal/kg (8,000 to 10,000 Btu/lb) are considered to be feasible. Below this value, the unblended fuel would not be likely to maintain a stable flame, and its combustion would release insufficient energy to provide needed steam generation potential in the boiler or the necessary heat for an industrial furnace. Some wastes with heating values of less than 4,400 kcal/kg (8,000 Btu/lb)

can be used if sufficient auxiliary fuel is employed to support combustion or if special designs are incorporated into the combustion device. Occasionally, for wastes with heating values higher than virgin fuels, blending with auxiliary fuel may be required to prevent overheating or overcharging the combustion device.

In combustion devices designed to burn liquid fuels, the viscosity of liquid waste must be low enough that the liquid can be atomized in the combustion chamber. If the viscosity is too high, heating of storage tanks may be required prior to combustion. For atomization of liquids, a viscosity of 165 centistokes (750 Saybolt Seconds Universal (SSU)) or less is typically required.

Filterable material suspended in the liquid fuel may prevent or hinder pumping or atomization.

Sulfur content in the waste may prevent burning of the waste because of potential atmospheric emissions of sulfur oxides. For instance, there are proposed Federal sulfur oxide emission regulations for certain new source industrial boilers (51 FR 22385). Air pollution control devices are available to remove sulfur oxides from the stack gases.

(2) Underlying principles of operation. For a boiler and most industrial furnaces, there are two distinct principles of operation. Initially, energy in the form of heat is transferred to the waste to achieve volatilization of the various waste constituents. For liquids, volatilization energy may also be supplied by using pressurized atomization. The energy used to pressurize the liquid waste allows the atomized waste to break into smaller particles, thus enhancing its rate

of volatilization. The volatilized constituents then require additional energy to destabilize the chemical bonds and allow the constituents to react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the chemical bonds is referred to as the energy of activation.

(3) Description of the fuel substitution process. As stated, a number of industrial applications can use fuel substitution. Therefore, there is no one process description that will fit all of these applications. However, the following section provides a general description of industrial kilns (one form of industrial furnace) and industrial boilers.

(a) Kilns. Combustible wastes have the potential to be used as fuel in kilns and, for waste liquids, are often used with oil to co-fire kilns. Coal-fired kilns are capable of handling some solid wastes. In the case of cement kilns, there are usually no residuals requiring land disposal since any ash formed becomes part of the product or is removed by particulate collection systems and recycled back to the kiln. The only residuals may be low levels of unburned gases escaping with combustion products. If this is the case, air pollution control devices may be required.

Three types of kilns are particularly applicable: cement kilns, lime kilns, and lightweight aggregate kilns.

(i) Cement kilns. The cement kiln is a rotary furnace, which is a refractory-lined steel shell used to calcine a mixture of calcium, silicon, aluminum, iron, and magnesium-containing minerals. The kiln is

normally fired by coal or oil. Liquid and solid combustible wastes may then serve as auxiliary fuel. Temperatures within the kiln are typically between 1,380 and 1,540°C (2,500 to 2,800°F). To date, only liquid hazardous wastes have been burned in cement kilns.

Most cement kilns have a dry particulate collection device (i.e., either an electrostatic precipitator or baghouse), with the collected fly ash recycled back to the kiln. Buildup of metals or other noncombustibles is prevented through their incorporation in the product cement. Since many types of cement require a source of chloride, most halogenated liquid hazardous wastes currently can be burned in cement kilns. Available information shows that scrubbers are not used.

(ii) Lime kilns. Quick-lime (CaO) is manufactured in a calcination process using limestone (CaCO_3) or dolomite (CaCO_3 and MgCO_3). These raw materials are also heated in a refractory-lined rotary kiln, typically to temperatures of 980 to 1,260°C (1,800 to 2,300°F). Lime kilns are less likely to burn hazardous wastes than are cement kilns because product lime is often added to potable water systems. Only one lime kiln currently burns hazardous waste in the U.S. That particular facility sells its product lime for use as flux or as refractory in blast furnaces.

As with cement kilns, any collected fly ash is recycled back to the lime kiln, resulting in no residual streams from the kiln. Available information shows that scrubbers are not used.

(iii) Lightweight aggregate kilns. Lightweight aggregate kilns heat clay to produce an expanded lightweight inorganic material used in portland cement formulations and other applications. The kiln has a normal temperature range of 1,100 to 1,150°C (2,000 to 2,100°F). Lightweight aggregate kilns are less amenable to combustion of hazardous wastes as fuels than the other kilns described above because of the lack of material in the kiln to adsorb halogens. As a result, burning of halogenated organics in these kilns would likely require afterburners to ensure complete destruction of the halogenated organics and scrubbers to control acid gas production. Such controls would produce a wastewater residual stream subject to treatment standards.

(b) Industrial boilers. A boiler is a closed vessel in which water is transformed into steam by the application of heat. Normally, heat is supplied by the combustion of pulverized coal, fuel oil, or gas. These fuels are fired into a combustion chamber with nozzles and burners that provide mixing with air. Liquid wastes, and granulated solid wastes in the case of grate-fired boilers, can be burned as auxiliary fuel in a boiler. Few grate-fired boilers burn hazardous wastes, however. For liquid-fired boilers, residuals requiring land disposal are generated only when the boiler is shut down and cleaned. This is generally done once or twice per year. Other residuals from liquid-fired boilers would be the gas emission stream, which would consist of any products of incomplete combustion, along with the normal combustion products. For example, chlorinated wastes would produce acid gases. If this is the case, air pollution control devices may be required. For solid-fired

boilers, an ash normally is generated. This ash may contain residual amounts of organics from the blended waste/fuels, as well as noncombustible materials. Land disposal of this ash would require compliance with applicable BDAT treatment standards.

(4) Waste characteristics affecting performance. For cement kilns and lime kilns and for lightweight aggregate kilns burning nonhalogenated wastes (i.e., no scrubber is needed to control acid gases), no residual waste streams would be produced. Any noncombustible material in the waste would leave the kiln in the product stream. As a result, in transferring standards EPA would not examine waste characteristics affecting performance but rather would determine the applicability of fuel substitution. That is, EPA would investigate the parameters affecting treatment selection. As mentioned previously, for kilns these parameters are Btu content, percent filterable solids, halogenated organics content, viscosity, and sulfur content.

Lightweight aggregate kilns burning halogenated organics and boilers burning wastes containing any noncombustibles will produce residual streams subject to treatment standards. In determining whether fuel substitution is likely to achieve the same level of performance on an untreated waste as on a previously treated waste, EPA will examine: (1) relative volatility of the waste constituents, (2) the heat transfer characteristics (for solids), and (3) the activation energy for combustion.

(a) Relative volatility. The term relative volatility (α) refers to the ease with which a substance present in a solid or liquid waste will vaporize from that waste upon application of heat from an external source. Hence, it bears a relationship to the equilibrium vapor pressure of the substance.

EPA recognizes that the relative volatilities cannot be measured or calculated directly for the types of wastes generally treated in an industrial boiler or furnace. The Agency believes that the best measure of relative volatility is the boiling point of the various hazardous constituents, and will, therefore, use this parameter in assessing volatility of the organic constituents.

(b) Heat transfer characteristics. Consistent with the underlying principles of combustion in aggregate kilns or boilers, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of industrial boilers burning solid fuels, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given boiler it can be assumed that the type of waste will have a minimal impact on the heat transferred from radiation. With regard to convection, EPA believes that the range of wastes treated would exhibit similar properties with regard to the amount of heat transferred by convection. Therefore, EPA will not evaluate radiation convection heat transfer properties of wastes in determining similar treatability. For solids, the third heat transfer mechanism, conductivity, is the one principally operative or most likely to vary between wastes.

Using thermal conductivity measurements as part of a treatability comparison for two different wastes through a given boiler or furnace is most meaningful when applied to wastes that are homogeneous. As wastes exhibit greater degrees of nonhomogeneity, thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance and not heat flow through all parts of the waste). Nevertheless, EPA has not identified a better alternative to thermal conductivity, even for wastes that are nonhomogeneous.

Other parameters considered for predicting heat transfer characteristics were Btu value, specific heat, and ash content. These parameters can neither better account for nonhomogeneity nor better predict heat transferability through the waste.

(c) Activation energy. Given an excess of oxygen, an organic waste in an industrial furnace or boiler would be expected to convert to carbon dioxide and water provided that the activation energy is achieved. Activation energy is the quantity of heat (energy) needed to destabilize molecular bonds and create reactive intermediates so that the oxidation (combustion) reaction will proceed to completion. As a measure of activation energy, EPA is using bond dissociation energies. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case.

In some instances, bond energies will not be available and will have to be estimated, or other energy effects (e.g., vibrational) and other reactions will have a significant influence on activation energy. Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested to a tested waste. These parameters included heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction). Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of available kinetic data was rejected because while such data could be used to calculate some free energy values (ΔG), they could not be used for the wide range of hazardous constituents. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct comparison.

(5) Design and operating parameters.

(a) Design parameters. Cement kilns and lime kilns, along with aggregate kilns burning nonhalogenated wastes, produce no residual streams. Their design and operation is such that any wastes that are

incompletely destroyed will be contained in the product. As a result, the Agency will not look at design and operating values for such devices since treatment, per se, cannot be measured through detection of constituents in residual streams. In this instance, it is important merely to ensure that the waste is appropriate for combustion in the kiln and that the kiln is operated in a manner that will produce a usable product.

Specifically, cement, lime, and aggregate kilns are demonstrated only on liquid hazardous wastes. Such wastes must be sufficiently free of filterable solids to avoid plugging the burners at the hot end of the kiln. Viscosity also must be low enough for the waste to be injected into the kiln through the burners. The sulfur content is not a concern unless the concentration in the waste is sufficiently high as to exceed Federal, State, or local air pollution standards promulgated for industrial boilers.

The design parameters that normally affect the operation of an industrial boiler (and aggregate kilns with residual streams) with respect to hazardous waste treatment are (1) the design temperature, (2) the design retention time of the waste in the combustion chamber, and (3) turbulence in the combustion chamber. Evaluation of these parameters would be important in determining whether an industrial boiler or industrial furnace is adequately designed for effective treatment of hazardous wastes. The rationale for selection of these three parameters is given below.

(i) Design temperature. Industrial boilers are generally designed based on their steam generation potential (Btu output). This factor is related to the design combustion temperature, which in turn depends on the amount of fuel burned and its Btu value. The fuel feed rates and combustion temperatures of industrial boilers are generally fixed based on the Btu values of fuels normally handled (e.g., No. 2 versus No. 6 fuel oils). When wastes are to be blended with fossil fuels for combustion, the blending, based on Btu values, must be such that the resulting Btu value of the mixture is close to that of the fuel value used in design of the boiler. Industrial furnaces also are designed to operate at specific ranges of temperature in order to produce the desired product (e.g., lightweight aggregate). The blended waste/fuel mixture should be capable of maintaining the design temperature range.

(ii) Design retention time. A sufficient retention time of combustion products is normally necessary to ensure that the hazardous substances being combusted (or formed during combustion) are completely oxidized. Retention times on the order of a few seconds are generally needed at normal operating conditions. For industrial furnaces as well as boilers, the retention time is a function of the size of the furnace and the fuel feed rates. For most boilers and furnaces, the retention time usually exceeds a few seconds.

(iii) Turbulence. Boilers are designed so that fuel and air are intimately mixed. This helps ensure that complete combustion takes place. The shape of the boiler and the method of fuel and air feed

influence the turbulence required for good mixing. Industrial furnaces also are designed for turbulent mixing where fuel and air are mixed.

(b) Operating parameters. The operating parameters that normally affect the performance of an industrial boiler and many industrial furnaces with respect to treatment of hazardous wastes are (1) air feed rate, (2) fuel feed rate, (3) steam pressure or rate of production, and (4) temperature. EPA believes that these four parameters will be used to determine whether an industrial boiler burning blended fuels containing hazardous waste constituents is properly operated. The rationale for selection of these four operating parameters is given below. Most industrial furnaces will monitor similar parameters, but some exceptions are noted.

(i) Air feed rate. An important operating parameter in boilers and many industrial furnaces is the oxygen content in the flue gas, which is a function of the air feed rate. Stable combustion of a fuel generally occurs within a specific range of air-to-fuel ratios. An oxygen analyzer in the combustion gases can be used to control the feed ratio of air to fuel to ensure complete thermal destruction of the waste and efficient operation of the boiler. When necessary, the air feed rate can be increased or decreased to maintain proper fuel-to-oxygen ratios. Some industrial furnaces do not completely combust fuels (e.g., coke ovens and blast furnaces); therefore, oxygen concentration in the flue gas is a meaningless variable.

(ii) Fuel feed rate. The rate at which fuel is injected into the boiler or industrial furnace will determine the thermal output of the system per unit of time (Btu/hr). If steam is produced, steam pressure monitoring will indirectly determine whether the fuel feed rate is adequate. However, various velocity and mass measurement devices can be used to monitor fuel flow directly.

(iii) Steam pressure or rate of production. Steam pressure in boilers provides a direct measure of the thermal output of the system and is directly monitored by use of in-system pressure gauges. Increases or decreases in steam pressure can be effected by increasing or decreasing the fuel and air feed rates within certain operating design limits. Most industrial furnaces do not produce steam, but instead produce a product (e.g., cement, aggregate) and monitor the rate of production.

(iv) Temperature. Temperatures are monitored and controlled in industrial boilers to ensure the quality and flow rate of steam. Therefore, complex monitoring systems are frequently installed in the combustion unit to provide a direct reading of temperature. The efficiency of combustion in industrial boilers is dependent on combustion temperatures. Temperature may be adjusted to design settings by increasing or decreasing the air and fuel feed rates.

Wastes should not be added to primary fuels until the boiler temperature reaches the minimum needed for destruction of the wastes. Temperature instrumentation and control should be designed to stop waste addition in the event of process upsets.

Monitoring and control of temperature in industrial furnaces are also critical to the product quality. For example, lime, cement, or aggregate kilns require minimum operating temperatures. Kilns have very high thermal inertia in the refractory and in-process product, high residence times, and high air feed rates, so that even in the case of a momentary stoppage of fuel flow to the kiln, organic constituents are likely to continue to be destroyed. The main operational control required for wastes burned in kilns is to stop waste flow in the event of low kiln temperature, loss of electrical power to the combustion air fan, and loss of primary fuel flow.

(v) Other operating parameters. In addition to the four operating parameters discussed above, EPA considered and then discarded one additional parameter--fuel-to-waste blending ratios. While the blending is done to yield a uniform Btu content fuel, blending ratios will vary widely depending on the Btu content of the wastes and the fuels being used.

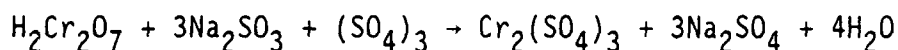
3.2.3 Chromium Reduction

(1) Applicability and use of chromium reduction. The process of hexavalent chromium (Cr^{6+}) reduction involves conversion from the hexavalent form to the trivalent form of chromium. This technology has wide application to hexavalent chromium wastes, including plating solutions, stainless steel acid baths and rinses, "chrome conversion" coating process rinses, and chromium pigment manufacturing wastes. Because this technology requires the pH to be in the acidic range, it would not be applicable to a waste that contains significant amounts of

cyanide or sulfide. In such cases, lowering of the pH can generate toxic gases such as hydrogen cyanide or hydrogen sulfide. It is important to note that additional treatment is required to remove trivalent chromium from solution.

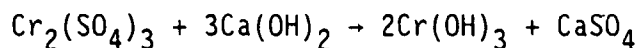
(2) Underlying principles of operation. The basic principle of treatment is to reduce the valence of chromium in solution (in the form of chromate or dichromate ions) from the valence state of six (+6) to the trivalent (+3) state. "Reducing agents" used to effect the reduction include sodium bisulfite, sodium metabisulfite, sulfur dioxide, sodium hydrosulfide, or the ferrous form of iron.

A typical reduction equation, using sodium sulfite as the reducing agent, is:



The reaction is usually accomplished at pH values in the range of 2 to 3.

At the completion of the chromium reduction step, the trivalent chromium compounds are precipitated from solution by raising the pH to a value exceeding about 8. The less soluble trivalent chromium (in the form of chromium hydroxide) is then allowed to settle from solution. The precipitation reaction is as follows:

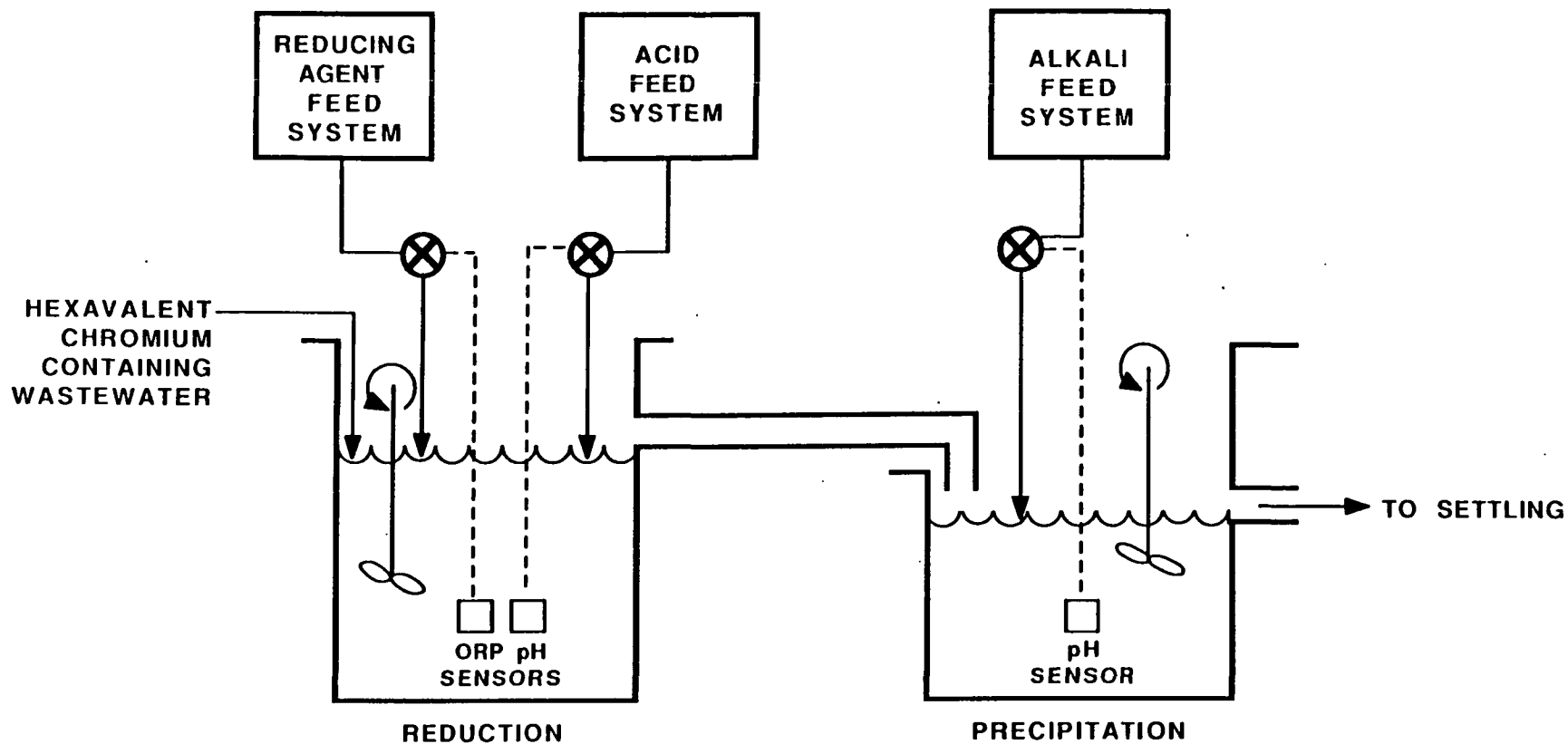


(3) Description of the chromium reduction process. The chromium reduction treatment process can be operated in a batch or continuous mode. A batch system will consist of a reaction tank, a mixer to homogenize the contents of the tank, a supply of reducing agent, and a source of acid and base for pH control.

A continuous chromium reduction treatment system, as shown in Figure 3-5, will usually include a holding tank upstream of the reaction tank for flow and concentration equalization. It will also include instrumentation to automatically control the amount of reducing agent added and the pH of the reaction tank. The amount of reducing agent is controlled by the use of a sensor called an oxidation reduction potential (ORP) cell. The ORP sensor electronically measures, in millivolts, the level to which the redox reaction has proceeded at any given time. It must be noted, however, that the ORP reading is very pH dependent. Consequently, if the pH is not maintained at a steady value, the ORP will vary somewhat, regardless of the level of chromate reduction.

(4) Waste characteristics affecting performance. In determining whether chromium reduction can treat an untested waste to the same level of performance as a previously tested waste, EPA will examine waste characteristics that affect the reaction involved with either lowering the pH or reducing the hexavalent chromium. EPA believes that such characteristics include the oil and grease content of the waste, total dissolved solids, and the presence of other compounds that would undergo reduction reaction.

(a) Oil and grease. EPA believes that these compounds could potentially interfere with the oxidation-reduction reactions, as well as cause monitoring problems by fouling of instrumentation (e.g., electrodes). Oil and grease concentrations can be measured by EPA Methods 9070 and 9071.



3-41

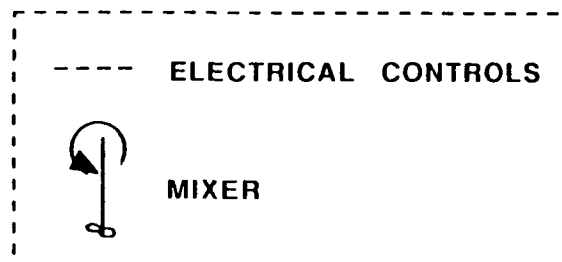


FIGURE 3-5
CONTINUOUS HEXAVALENT
CHROMIUM REDUCTION SYSTEM

(b) Total dissolved solids. These compounds can interfere with the addition of treatment chemicals into solution and possibly cause monitoring problems.

(c) Other reducible compounds. These compounds would generally consist of other metals in the waste. Accordingly, EPA will evaluate the type and concentration of other metals in the waste in evaluating transfer of treatment performances.

(5) Design and operating parameters. The parameters that EPA will examine in assessing the design and operation of a chromium reduction treatment system are discussed below.

(a) Treated and untreated design concentration. EPA will need to know the level of performance that the facility is designed to achieve in order to ensure that the design is consistent with best demonstrated practices. This parameter is important in that a system will not usually perform better than its design. In addition to knowing the treated design concentration, it is important to know the characteristics of the untreated waste that the system is designed to handle. Accordingly, EPA will obtain data on the untreated wastes to ensure that waste characteristics fall within design specifications.

(b) Reducing agent. The choice of a reducing agent establishes the chemical reaction upon which the chromium reduction system is based. The amount of reducing agent needs to be monitored and controlled in both batch and continuous systems. In batch systems, reducing agent is usually controlled by analysis of the hexavalent chromium remaining in solution. For continuous systems, the ORP reading is used to monitor and control the addition of reducing agent.

ORP will change slowly until the correct amount of reducing agent has been added, at which point ORP will change rapidly, indicating reaction completion. The set point for the ORP monitor is approximately the reading just after the rapid change has begun. The reduction system must then be monitored periodically to determine whether the selected setpoint needs further adjustment.

(c) pH. For batch and continuous systems, pH is an important parameter because of its effect on the reduction reaction. For a batch system, pH can be monitored intermittently during treatment. For continuous systems, the pH should be continuously monitored because of its effect on ORP. In evaluating the design and operation of a continuous chromium reduction system, it is important to know the pH on which the design ORP value is based, as well as the designed ORP value.

(d) Retention time. Retention time should be adequate to ensure that the hexavalent chromium reduction reaction goes to completion. In the case of the batch reactor, the retention time is varied by adjusting treatment time in the reaction tank. If the process is continuous, it is important to monitor the feed rate to ensure that the designed residence time is achieved.

3.2.4 Chemical Precipitation

(1) Applicability and use of chemical precipitation. Chemical precipitation is used when dissolved metals are to be removed from solution. This technology can be applied to a wide range of wastewaters containing dissolved BDAT list metals and other metals as well. This treatment process has been practiced widely by industrial facilities since the 1940s.

(2) Underlying principles of operation. The underlying principle of chemical precipitation is that metals in wastewater are removed by the addition of a treatment chemical that converts the dissolved metal to a metal precipitate. This precipitate is less soluble than the original metal compound and therefore settles out of solution, leaving a lower concentration of the metal present in the solution. The principal chemicals used to convert soluble metal compounds to the less soluble forms include lime ($\text{Ca}(\text{OH})_2$), caustic (NaOH), sodium sulfide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulfide (FeS).

The solubility of a particular compound depends on the extent to which the electrostatic forces holding the ions of the compound together can be overcome. The solubility changes significantly with temperature; most metal compounds are more soluble as the temperature increases. Additionally, the solubility is affected by the other constituents present in a waste. As a general rule, nitrates, chlorides, and sulfates are more soluble than hydroxides, sulfides, carbonates, and phosphates.

An important concept related to treatment of the soluble metal compounds is pH. This term provides a measure of the extent to which a solution contains an excess of either hydrogen or hydroxide ions. The pH scale ranges from 0 to 14, with 0 being the most acidic, 14 representing the highest alkalinity or hydroxide ion (OH^-) content, and 7.0 being neutral.

When hydroxide is used, as is often the case, to precipitate the soluble metal compounds, the pH is frequently monitored to ensure that sufficient treatment chemicals are added. It is important to point out that pH is not a good measure of treatment chemical addition for compounds other than hydroxides; when sulfide is used, for example, facilities might use an oxidation-reduction potential (ORP) meter correlation to ensure that sufficient treatment chemical is used.

Following conversion of the relatively soluble metal compounds to metal precipitates, the effectiveness of chemical precipitation is a function of the physical removal, which usually relies on a settling process. A particle of a specific size, shape, and composition will settle at a specific velocity, as described by Stokes' Law. For a batch system, Stokes' Law is a good predictor of settling time because the pertinent particle parameters remain essentially constant. Nevertheless, in practice, settling time for a batch system is normally determined by empirical testing. For a continuous system, the theory of settling is complicated by factors such as turbulence, short-circuiting, and velocity gradients, thereby increasing the importance of the empirical tests.

(3) Description of the chemical precipitation process. The equipment and instrumentation required for chemical precipitation vary depending on whether the system is batch or continuous. Both operations are discussed below; a schematic of the continuous system is shown in Figure 3-6.

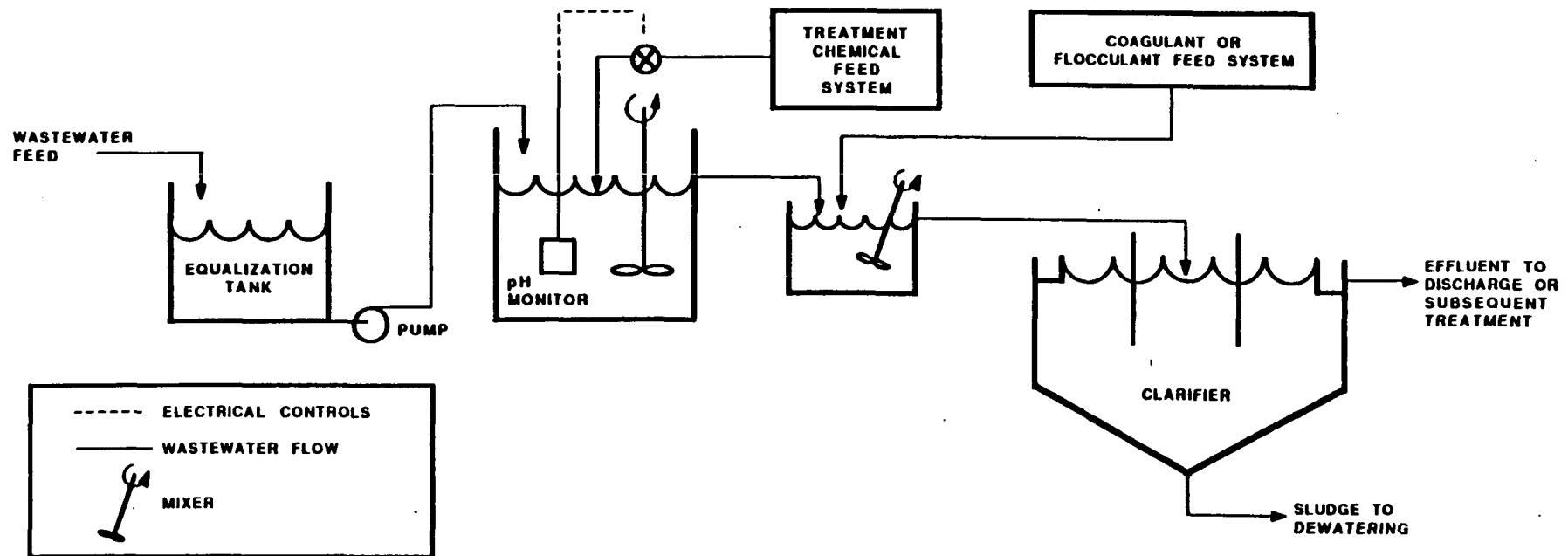


FIGURE 3-6 CONTINUOUS CHEMICAL PRECIPITATION

For a batch system, chemical precipitation requires only a feed system for the treatment chemicals and a second tank where the waste can be treated and allowed to settle. When lime is used, it is usually added to the reaction tank in a slurry form. In a batch system, the supernate is usually analyzed before discharge, thus minimizing the need for instrumentation.

In a continuous system, additional tanks are necessary, as well as instrumentation to ensure that the system is operating properly. In this system, the first tank that the wastewater enters is referred to as an equalization tank. This is where the waste can be mixed to provide more uniformity, minimizing wide swings in the type and concentration of constituents being sent to the reaction tank. It is important to reduce the variability of the waste sent to the reaction tank because control systems inherently are limited with regard to the maximum fluctuations that can be managed.

Following equalization, the waste is pumped to a reaction tank where treatment chemicals are added; this is done automatically by using instrumentation that senses the pH of the system and then pneumatically adjusts the position of the treatment chemical feed valve so that the design pH value is achieved. Both the complexity and the effectiveness of the automatic control system will vary depending on the variation in the waste and the pH range that is needed to properly treat the waste.

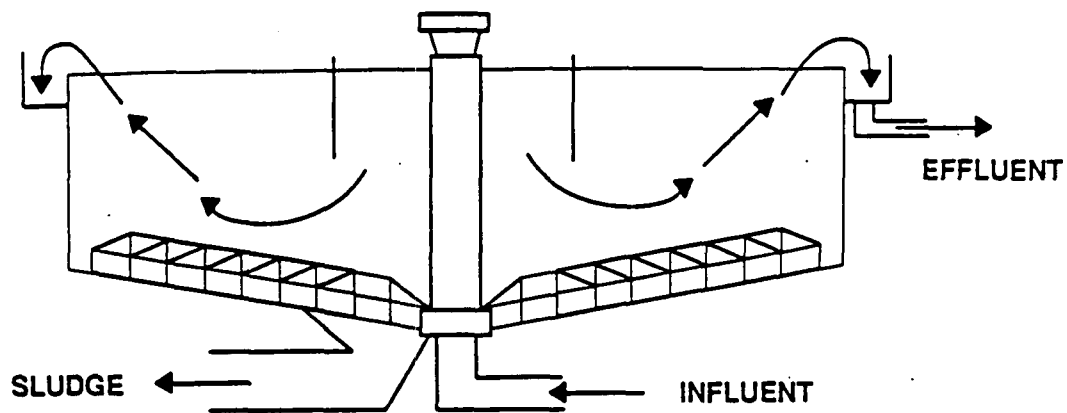
An important aspect of the reaction tank design is that the tank's contents be well mixed so that the waste and the treatment chemicals are both dispersed throughout the tank to ensure commingling of the reactant

and the treatment chemicals. In addition, effective dispersion of the treatment chemicals throughout the tank is necessary to properly monitor and thereby control the amount of treatment chemicals added.

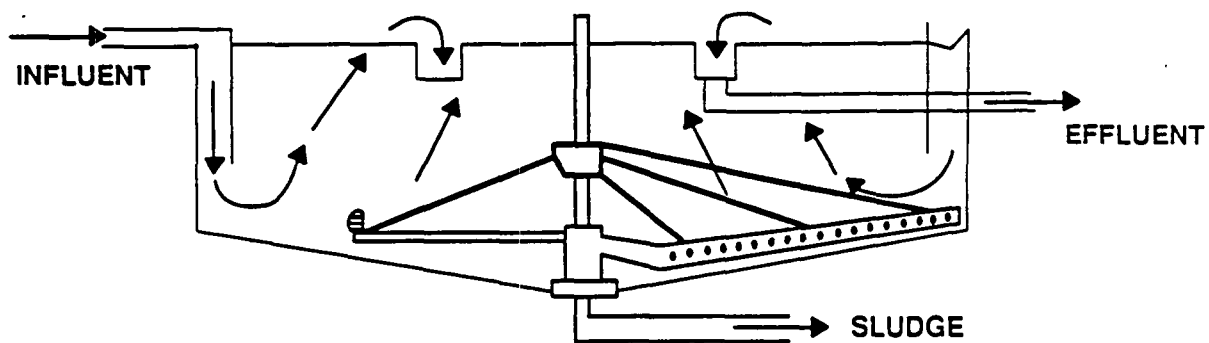
After the waste is reacted with the treatment chemical, it flows to a quiescent tank where the precipitate is allowed to settle and subsequently to be removed. Settling can be chemically assisted through the use of flocculating compounds. Flocculants increase the particle size and density of the precipitated solids, both of which increase the rate of settling. The particular flocculating agent that will best improve settling characteristics will vary depending on the particular waste; selection of the flocculating agent is generally accomplished by performing laboratory bench tests. Settling can be conducted in a large tank by relying solely on gravity or can be mechanically assisted through the use of a circular clarifier or an inclined separator. Schematics of the latter two separators are shown in Figures 3-7 and 3-8.

Filtration can be used for further removal of precipitated residuals both in cases where the settling system is underdesigned and in cases where the particles are difficult to settle. Polishing filtration is discussed in a separate technology section.

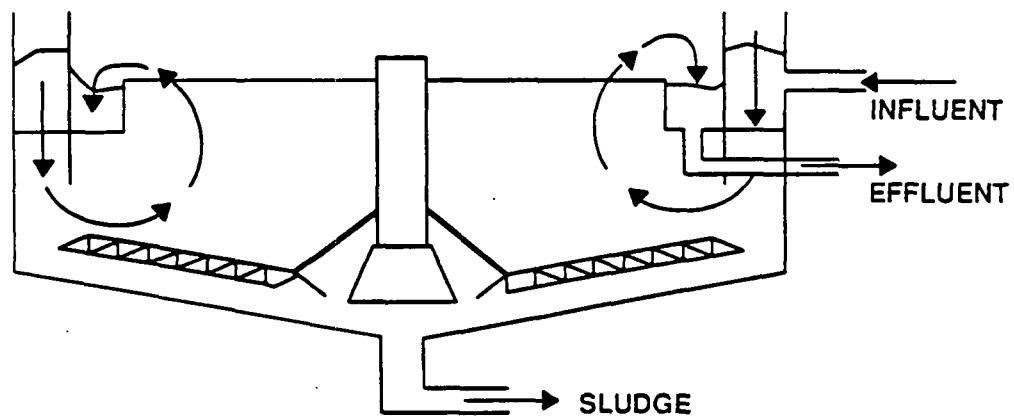
(4) Waste characteristics affecting performance. In determining whether chemical precipitation is likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA will examine the following waste characteristics: (1) the concentration and type of the metal(s) in the waste, (2) the concentration of total suspended solids (TSS), (3) the concentration of total dissolved solids



CENTER FEED CLARIFIER WITH SCRAPER SLUDGE REMOVAL SYSTEM



RIM FEED - CENTER TAKEOFF CLARIFIER WITH HYDRAULIC SUCTION SLUDGE REMOVAL SYSTEM



RIM FEED - RIM TAKEOFF CLARIFIER

FIGURE 3-7 CIRCULAR CLARIFIERS

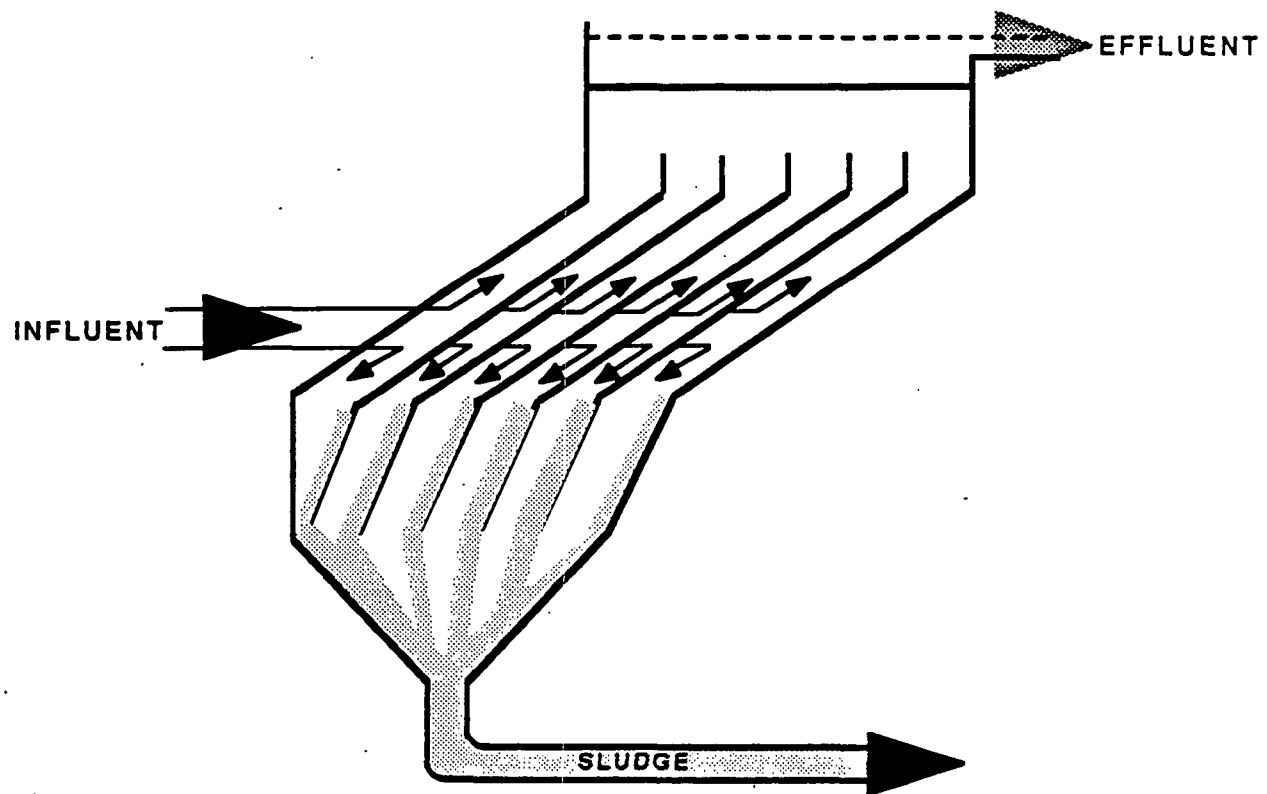


FIGURE 3-8
INCLINED PLATE SETTLER

(TDS), (4) whether the metal exists in the wastewater as a complex, and (5) the oil and grease content. These parameters affect the chemical reaction of the metal compound, the solubility of the metal precipitate, or the ability of the precipitated compound to settle.

(a) Concentration and type of metals. For most metals, there is a specific pH at which the metal hydroxide is least soluble. As a result, when a waste contains a mixture of many metals, it is not possible to operate a treatment system at a single pH that is optimal for the removal of all metals. The extent to which this situation affects treatment depends on the particular metals to be removed and their concentrations. One approach is to operate multiple precipitations, with intermediate settling, when the optimum pH occurs at markedly different levels for the metals present. The individual metals and their concentrations can be measured using EPA Method 6010.

(b) Concentration and type of total suspended solids (TSS). Certain suspended solid compounds are difficult to settle because of their particle size or shape. Accordingly, EPA will evaluate this characteristic in assessing the transfer of treatment performance. Total suspended solids can be measured by EPA Wastewater Test Method 160.2.

(c) Concentration of total dissolved solids (TDS). Available information shows that total dissolved solids can inhibit settling. The literature states that poor flocculation is a consequence of high TDS and shows that higher concentrations of total suspended solids are found in treated residuals. Poor flocculation can adversely affect the degree to which precipitated particles are removed. Total dissolved solids can be measured by EPA Wastewater Test Method 160.1.

(d) Complexed metals. Metal complexes consist of a metal ion surrounded by a group of other inorganic or organic ions or molecules (often called ligands). In the complexed form, the metals have a greater solubility and therefore may not be as effectively removed from solution by chemical precipitation. EPA does not have an analytical method to determine the amount of complexed metals in the waste. The Agency believes that the best measure of complexed metals is to analyze for some common complexing compounds (or complexing agents) generally found in wastewater for which analytical methods are available. These complexing agents include ammonia, cyanide, and EDTA. The analytical method for cyanide is EPA Method 9010, while the method for EDTA is ASTM Method D3113. Ammonia can be analyzed using EPA Wastewater Test Method 350.

(e) Oil and grease content. The oil and grease content of a particular waste directly inhibits the settling of the precipitate. Suspended oil droplets float in water and tend to suspend particles such as chemical precipitates that would otherwise settle out of the solution. Even with the use of coagulants or flocculants, the separation of the precipitate is less effective. Oil and grease content can be measured by EPA Method 9071.

(5) Design and operating parameters. The parameters that EPA will evaluate when determining whether a chemical precipitation system is well designed are (1) design value for treated metal concentrations, as well as other characteristics of the waste used for design purposes (e.g., total suspended solids); (2) pH; (3) residence time; (4) choice of

treatment chemical; (5) choice of coagulant/flocculant; and (6) mixing. The reasons for which EPA believes these parameters are important to a design analysis are cited below, along with an explanation of why other design criteria are not included in this analysis.

(a) Treated and untreated design concentrations. When determining whether to sample a particular facility, EPA pays close attention to the treated concentration that the system is designed to achieve. Since the system will seldom outperform its design, EPA must evaluate whether the design is consistent with best demonstrated practice.

The untreated concentrations that the system is designed to treat are important in evaluating any treatment system. Operation of a chemical precipitation treatment system with untreated waste concentrations in excess of design values can easily result in poor performance.

(b) pH. The pH is important because it can indicate that sufficient treatment chemical (e.g., lime) has been added to convert the metal constituents in the untreated waste to forms that will precipitate. The pH also affects the solubility of metal hydroxides and sulfides and thus directly impacts the effectiveness of removal. In practice, the design pH is determined by empirical bench testing, often referred to as "jar" testing. The temperature at which the "jar" testing is conducted is important since it also affects the solubility of the metal precipitates. Operation of a treatment system at temperatures above the design temperature can result in poor performance. In assessing the operation of a chemical precipitation system, EPA prefers to use continuous data on the pH and periodic temperature conditions throughout the treatment period.

(c) Residence time. Residence time is important because it impacts the completeness of the chemical reaction to form the metal precipitate and, to a greater extent, the amount of precipitate that settles out of solution. In practice, it is determined by "jar" testing. For continuous systems, EPA will monitor the feed rate to ensure that the system is operated at design conditions. For batch systems, EPA will want information on the design parameter used to determine sufficient settling time (e.g., total suspended solids).

(d) Choice of treatment chemical. A choice must be made as to what type of precipitating agent (i.e., treatment chemical) will be used. The factor that most affects this choice is the type of metal constituents to be treated. Other design parameters, such as pH, residence time, and choice of coagulant/flocculant agents, are based on the selection of the treatment chemical.

(e) Choice of coagulant/flocculant. This is important because these compounds improve the settling rate of the precipitated metals and allow smaller systems (i.e., those with a lower retention time) to achieve the same degree of settling as much larger systems. In practice, the choice of the best agent and the required amount is determined by "jar" testing.

(f) Mixing. The degree of mixing is a complex assessment that includes, the energy supplied, the time the material is mixed, and the related turbulence effects of the specific size and shape of the tank. In its analysis, EPA will consider whether mixing is provided and whether

the type of mixing device is one that could be expected to achieve uniform mixing. For example, EPA may not use data from a chemical precipitation treatment system in which an air hose was placed in a large tank to achieve mixing.

4. PERFORMANCE DATA BASE.

This section presents performance data associated with the demonstrated technologies for K015 waste. Performance data include the BDAT list constituent concentrations in the untreated and treated waste samples, the operating data collected during treatment of the sampled waste, design values for the treatment technologies, and data on waste characteristics that affect performance. EPA has presented all such data to the extent that they are available.

EPA's use of these data in determining the technologies that represent BDAT, and in developing treatment standards, is described in Sections 5 and 7, respectively.

4.1 BDAT List Organics Treatment Data

EPA tested liquid injection incineration to demonstrate the actual performance achievable by the technology for treatment of K015. The Agency has three data sets (matched pairs of treated and untreated data points) for BDAT list organics as well as the appropriate design and operating data. Performance data collected for liquid injection incineration of K015 are presented in Table 4-1 at the end of this section. Further discussion of how these data were obtained is presented in the Onsite Engineering Report of Treatment Technology Performance and Operation for Incineration of K015 Waste at the John Zink Company Test Facility (USEPA 1987a).

Unadjusted analytical data show that in the untreated waste for which detection limits were fairly high (parts per thousand for semivolatile organic compounds), only benzal chloride was detected. Concentrations

detected ranged upward from 88 percent. Benzal chloride concentrations in the treated wastewaters ranged from less than 0.050 to 0.094 mg/l. Other organic constituents found in the treated waste were toluene, anthracene, benzo(b and/or k)fluoranthene, and phenanthrene. These constituents were detected at concentrations up to 0.210 mg/l.

The Agency does not have performance data for treatment of the BDAT list organics present in K015 using fuel substitutions.

4.2 BDAT List Metals Treatment Data

The treatment wastewater residual from liquid injection incineration of K015 contains BDAT list metals in treatable concentrations. The Agency does not have performance data specifically for treatment of BDAT list metals in the scrubber water generated from liquid injection incineration of K015. However, EPA does have data from EPA's testing of a metal-bearing wastewater at Envirote Corporation that the Agency believes represent a level of treatment performance that can be achieved for the K015 scrubber water by using chromium reduction and chemical precipitation, primarily using lime as the treatment chemical.

The data collected for the Envirote treatment system consist of 11 sample sets. The untreated waste was a metal-containing wastewater that was a mixture of F006, F002, D003, and K062 wastewaters. The performance data for the Envirote wastewater treatment system are shown in Table 4-2 at the end of this section.

EPA reviewed the characterization data for the K015 scrubber water from liquid injection incineration, as well as data on parameters that would affect the performance of the Envirote treatment system. The

concentrations of the untreated metals in the Envirite wastewater are typically higher than the BDAT list metals in the K015 scrubber water. Specifically, the principal metals in the K015 scrubber are present at concentrations less than 35 mg/l for chromium and 25 mg/l for nickel. In the Envirite metal-containing wastewater, the concentrations of chromium and nickel are as high as 2,581 mg/l and 16,330 mg/l, respectively. In addition, both the Envirite wastewater and the K015 scrubber water have low oil and grease contents. In conclusion, these data indicate that the BDAT list metals in K015 scrubber water could be treated to the same levels as the Envirite metal-containing wastewater.

Table 4-1 Performance Data Collected by EPA for Liquid Injection
Incineration of K015 Waste

Sample set #1

Constituent	BDAT constituent concentration ^a	
	Untreated waste (mg/kg)	Treated waste ^b (mg/l)
<u>Volatiles</u>		
Toluene	<10	0.059
<u>Semivolatiles</u>		
Anthracene	<5,000	<0.050
Benzal chloride	930,000	<0.050
Benzo(b and/or k)fluoranthene	<5,000	<0.050
Phenanthrene	<5,000	<0.050
<u>Metals</u>		
Antimony	-	<0.17
Arsenic	-	0.25
Barium	-	0.11
Beryllium	-	<0.005
Cadmium	-	<0.02
Chromium	-	4.0
Copper	-	0.58
Mercury	-	0.005
Nickel	-	2.2
Lead	-	0.06
Selenium	-	0.06
Silver	-	0.13
Thallium	-	<0.75
Vanadium	-	0.05
Zinc	-	0.11

Design and operating data

Kiln

Temperature	1841-2013°F
Feed rate	4.14-4.5 lb/min
Excess oxygen	3.74-5.29%
Carbon monoxide	0-520 ppm

Scrubber

Flow	17.44 gal/min
Pressure drop	40-44 in. of water

^a Concentration data have not been adjusted for accuracy. Accuracy-adjusted data are shown in Section 6 and Appendix B.

^b The concentrations represent scrubber water residuals and are considered treated relative to organics and not relative to metals.

Table 4-1 (continued)

Sample set #2

Constituent	BDAT constituent concentration ^a	
	Untreated waste (mg/kg)	Treated waste ^b (mg/l)
<u>Volatiles</u>		
Toluene	<10	0.030
<u>Semivolatiles</u>		
Anthracene	<5,000	0.068
Benzal chloride	910,000	0.066
Benzo(b and/or k)fluoranthene	<5,000	<0.050
Phenanthrene	<5,000	0.058
<u>Metals</u>		
Antimony	-	<0.12
Arsenic	-	0.10
Barium	-	0.25
Beryllium	-	<0.005
Cadmium	-	<0.02
Chromium	-	18
Copper	-	1.6
Mercury	-	<0.0025
Nickel	-	11
Lead	-	0.24
Selenium	-	0.09
Silver	-	0.30
Thallium	-	<0.75
Vanadium	-	0.170
Zinc	-	0.75

Design and operating data

Kiln

Temperature	2001-2077°F
Feed rate	4.48-4.55 lb/min
Excess oxygen	3.29-5.12%
Carbon monoxide	0-80 ppm

Scrubber

Flow	17.44 gal/min
Pressure drop	40-41 in. of water

^a Concentration data have not been adjusted for accuracy. Accuracy-adjusted data are shown in Section 6 and Appendix B.

^b The concentrations represent scrubber water residuals and are considered treated relative to organics and not relative to metals.

Table 4-1 (continued)

Sample set #3

Constituent	BDAT constituent concentration ^a	
	Untreated waste (mg/kg)	Treated waste ^b (mg/l)
<u>Volatiles</u>		
Toluene	<10	0.015
<u>Semivolatiles</u>		
Anthracene	<5,000	0.210
Benzal chloride	1,100,000	0.094
Benzo(b and/or k)fluoranthene	<5,000	0.096
Phenanthrene	<5,000	0.110
<u>Metals</u>		
Antimony	-	0.16
Arsenic	-	0.53
Barium	-	0.55
Beryllium	-	<0.005
Cadmium	-	<0.02
Chromium	-	34
Copper	-	3.5
Mercury	-	0.06
Nickel	-	25
Lead	-	0.30
Selenium	-	0.06
Silver	-	<0.035
Thallium	-	<0.75
Vanadium	-	0.39
Zinc	-	0.93

Design and operating data

Kiln

Temperature	1780-2065°F
Feed rate	4.18-6.22 lb/min
Excess oxygen	3.17-5.77%
Carbon monoxide	0-614 ppm

Scrubber

Flow	17.44 gal/min
Pressure drop	38-40 in. of water

^aConcentration data have not been adjusted for accuracy. Accuracy adjusted data are shown in Section 6 and Appendix B.

^bTreated waste concentration data reflect the worst-case concentration from quench water sampling to ensure conservatism in determining a wastewater standard.

Table 4-2 Performance Data for Chromium Reduction and Chemical Precipitation
on Mixed Waste Sampled by EPA at Envirote Co.

Constituent/parameter	Concentration (ppm)							
	Sample Set #1		Sample Set #2		Sample Set #3		Sample Set #4	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
<u>BDAT Metals</u>								
Antimony	<10	<1	<10	<1	<10	<1	<10	-
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Barium	<10	<1	<10	<1	<10	3.5	<10	<10
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<2
Cadmium	13	<0.5	10	<0.5	<5	<0.5	<5	<5
Chromium (hexavalent)	893	0.011	807	0.190	775	- ^a	0.6	0.042
Chromium (total)	2,581	0.12	2,279	0.12	1,990	0.20	556	0.10
Copper	138	0.21	133	0.15	133	0.21	88	0.07
Lead	64	<0.01	54	<0.01	<10	<0.01	<10	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Nickel	471	0.33	470	0.33	16,330	0.33	6,610	0.33
Selenium	<10	<1	<10	<1	<10	<1	<10	<10
Silver	<2	<0.2	2	<0.2	<2	<0.3	<2	<2
Thallium	<10	<1	<10	<1	<10	<1	<10	<10
Zinc	116	0.125	4	0.115	3.9	0.140	84	1.62
<u>Other Parameters</u>								
Total organic carbon	2700		2800		500		2900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	2500		3600		0		900	

Table 4-2 (continued)

Constituent/parameter	Concentration (ppm)							
	Sample Set #5		Sample Set #6		Sample Set #7		Sample Set #8	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
<u>BDAT Metals</u>								
Antimony	<10	<1	<10	<1	<10	<1	<10	<1
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<0.1
Barium	<10	<1	<10	<2	<10	<1	<10	<1
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Cadmium	<5	<0.5	<5	<0.5	10	<0.5	<5	<0.5
Chromium (hexavalent)	917	0.058	734	- ^a	769	0.121	0.13	<0.01
Chromium (total)	2,236	0.11	2,548	0.10	2,314	0.12	831	0.15
Copper	91	0.14	149	0.12	72	0.16	217	0.16
Lead	18	<0.01	<10	<0.01	108	<0.01	212	<0.01
Mercury	1	<0.1	<1	<0.1	<1	<0.01	<1	<0.1
Nickel	1,414	0.310	588	0.33	426	0.40	669	0.36
Selenium	<10	<1	<10	<1	<10	<1	<10	<1
Silver	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1	<10	<1	<10	<1	<10	<1
Zinc	71	0.125	4	0.095	171	0.115	151	0.130
<u>Other Parameters</u>								
Total organic carbon	200		700		3400		5900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	0		700		1900		800	

Table 4-2 (continued)

Constituent/parameter	Concentration (ppm)					
	Sample Set #9		Sample Set #10		Sample Set #11	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
<u>BDAT Metals</u>						
Antimony	<10	<1	<10	<1	<10	<1.00
Arsenic	<1	<0.1	<1	<0.1	<1	<0.10
Barium	<10	<1	<10	<1	<12	<1.00
Beryllium	<2	<0.2	<2	<0.2	<2	<0.20
Cadmium	<5	<0.5	<5	<0.5	23	<5
Chromium (hexavalent)	0.07	0.041	0.08	0.106	0.30	<0.01
Chromium (total)	939	0.10	395	0.12	617	0.18
Copper	225	0.08	191	0.14	137	0.24
Lead	<10	<0.01	<10	<0.01	136	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.10
Nickel	940	0.33	712	0.33	382	0.39
Selenium	<10	<1.0	<10	<1	<10	<1.00
Silver	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1.0	<10	<1	<10	<1.00
Zinc	5	0.06	5	0.070	135	0.100
<u>Other Parameters</u>						
Total organic carbon	2100		0		52	
Total solids	-		-		-	
Total chlorides	-		-		-	
Total organic halides	0		<300		300	

- = Not analyzed.

^aHexavalent chromium was actually treated by chromium reduction prior to chemical precipitation and sludge filtration.

Note: Design and Operating Parameters are as follows:

pH during chromium reduction - 8.5 to 9.0.

Reducing agent - ferrous iron.

Ratio of reducing agent to hexavalent chromium - 3.2 to 10.

pH during chemical precipitation - 8 to 10.

Precipitation agents - lime and sulfide.

Filter type - vacuum filter.

Reference: USEPA 1986d.

5. IDENTIFICATION OF THE BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the rationale for the determination of best demonstrated available technology (BDAT) for K015 organics and metals treatment. As discussed in Section 1, the Agency examines all the available data for the demonstrated technologies to determine whether one of the technologies performs significantly better than the others. Next, the "best" performing treatment technology is evaluated to determine whether the resulting treatment is available. To be "available," a technology (1) must provide substantial treatment, and (2) must be commercially available to the affected industry. If the "best" technology is "available," then the technology represents BDAT.

5.1 BDAT for Treatment of Organics

For treatment of organics in K015, the Agency has data only from liquid injection incineration. The three data sets were collected during tests in which the K015 waste was incinerated. Because data from the other demonstrated technologies are not available, the Agency cannot compare performance to determine which technology is "best." However, the Agency would not expect the level of performance to be improved by other forms of incineration such as rotary kiln or fixed hearth. In addition, EPA believes that well-designed and well-operated fuel substitution systems could not achieve better treatment since they operate at approximately the same temperatures and turbulent conditions as a liquid injection incineration system.

Consistent with EPA's methodology for determining BDAT, the Agency evaluated the liquid injection incineration performance data to determine whether the technology provides substantial treatment for BDAT list organic constituents in K015.

As a first step in determining whether substantial treatment is provided, the available treatment data described in Section 4 were reviewed and assessed with regard to the design and operation of the treatment system, the analytical testing, and the quality assurance/quality control analyses of the data. In general, all of the performance data collected for liquid injection incineration of K015 were of sufficient quality for the determination of substantial treatment. Design and operating data were collected for the liquid injection incineration system used for treating BDAT list organic constituents in K015 wastes. These data indicate that the system was well designed and well operated during the test burn. In addition, the proper analytical tests were performed for the untreated wastes and the treated residuals. Specifically, because incineration is a destruction technology for organics, total constituent concentration of organics is used to measure treatment performance.

Next, EPA adjusted the data values based on the analytical recovery values to take into account analytical interferences associated with the chemical makeup of the treated sample. In summary, EPA first analyzes a waste for a constituent and then adds a known amount of the same constituent (i.e., spike) to the waste material. The total amount

recovered after spiking minus the initial concentration in the sample, all divided by the amount added, is the recovery value. The reciprocal of the recovery (EPA uses the lower value of the matrix spike and matrix duplicate recoveries, in general), multiplied by the performance data value, is the accuracy-corrected value used in determining substantial treatment and subsequently calculating treatment standards. Percent recovery values for the BDAT list constituents in the K015 performance data are presented in Appendix B. The accuracy correction values for the regulated organic constituents are presented in Table 7-1. (The methodology for adjusting the performance data is discussed in Section 1.)

EPA's determination that substantial treatment occurs is based on the reduction of the concentration of BDAT list organic constituents. For example, benzal chloride was detected in the untreated waste at concentrations greater than 910,000 mg/kg. Treated waste concentrations in the scrubber water ranged from <0.050 to 0.094 mg/l for benzal chloride. In addition to the substantial reduction, liquid injection incineration is commercially available and therefore meets the second criterion for "availability." As "best," "demonstrated," and "available," the technology represents BDAT for the organics present in K015.

5.2 BDAT for Treatment of Metals

Treatment of the BDAT list organics present in K015 using liquid injection incineration generates a wastewater residual that requires treatment for BDAT list metals. As discussed earlier, EPA does not

have treatment data specifically for K015 wastewaters generated from liquid injection incineration; however, EPA does have treatment data specifically for metal-containing wastewaters (Envirite) believed to be similar to K015 scrubber water. The demonstrated technologies identified for treatment of BDAT list metals in K015 scrubber water for which the Agency has data are chromium reduction and chemical precipitation. The treatment performance data for the BDAT list metals by chromium reduction and chemical precipitation were examined to determine whether substantial treatment had occurred. Since the operating data collected during treatment of this waste represent the performance of a well-designed, well-operated treatment system, all data were used in determining substantial treatment.

EPA's determination of substantial wastewater treatment for the Envirite treatment system is based on the reductions of hexavalent chromium from 917 mg/l to 0.058 mg/l, chromium from 2,581 mg/l to 0.12 mg/l, lead from 212 mg/l to 0.01 mg/l, copper from 225 mg/l to 0.08 mg/l, nickel from 16,330 mg/l to 0.33 mg/l, and zinc from 171 mg/l to 0.115 mg/l. The treated concentrations are accuracy-corrected values adjusted in the same manner described for the organic constituents.

The Agency has no reason to expect that the use of other processes could improve the level of performance; therefore, chromium reduction and chemical precipitation are "best." The treatment system consisting of chromium reduction followed by chemical precipitation is "available" because the components of the treatment system are commercially available

and the treatment provides substantial treatment. Therefore, this treatment system represents BDAT for BDAT list metals in K015 wastewaters.

6. SELECTION OF REGULATED CONSTITUENTS

As discussed in Section 1, the Agency has developed a list of hazardous constituents (Table 1-1) from which the constituents to be regulated are selected. EPA may revise this list as additional data and information become available. The list is divided into the following categories: volatile organics, semivolatile organics, metals, inorganics other than metals, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorus insecticides, PCBs, and dioxins and furans.

This section describes the process used to select the constituents to be regulated. The process involves developing a list of potential regulated constituents and then eliminating those constituents that would not be treated by the chosen BDAT or that would be controlled by regulation of the remaining constituents.

6.1 Identification of BDAT List Constituents in K015

As discussed in Sections 2 and 4, the Agency has characterization data as well as performance data from treatment of K015 waste. These data, as well as information on the waste generating process, have been used to determine which BDAT list constituents may be present in the waste and thus which ones are potential candidates for regulation in wastewater forms of K015.

Table 6-1, at the end of this section, indicates, for the untreated waste, which constituents were analyzed, which constituents were detected, and which constituents the Agency believes could be present though not detected. A few compounds have been added to the BDAT list of constituents since the treatment analysis for K015 was performed;

therefore, no analytical data exist for these constituents. While the Agency does not expect any of the additional compounds to be present in the K015 waste, these additional compounds are also noted on Table 6-1. Certain BDAT list categories were not analyzed in the untreated waste because there was not thought to be an in-process source of these constituents. These categories include all the constituents listed in the inorganics other than metals, organochlorine pesticides, phenoxyacetic herbicides, organophosphorus insecticides, PCBs, and dioxin/furans.

Under the column "Believed to be present," constituents other than those detected in the untreated waste are marked with Y if EPA believes they are likely to be present in the untreated waste. Those constituents marked with Y have been detected in the treated residual and therefore EPA believes that they are present in the untreated waste. Constituents may not have been detected in the untreated waste for one of several reasons: (1) none of the untreated waste samples were analyzed for those constituents, (2) masking or interference by other constituents prevented detection, or (3) the constituent indeed was not present.

Of the 231 current BDAT list constituents, the Agency analyzed for 162 constituents in the untreated waste. Eighteen BDAT constituents were not on the BDAT list at the time the K015 waste was analyzed; thus data do not exist for some of them. Other BDAT list constituents were not analyzed because the Agency believed that there was no in-process source for them.

Of the 162 BDAT list constituents analyzed in the untreated waste, only 1 was detected--benzal chloride. In the treated waste, i.e., scrubber water, 5 BDAT list organic constituents were detected.

BDAT list metals were not analyzed in the untreated waste but were analyzed in the treated waste (scrubber water). Of the 15 metals analyzed, 12 were detected in the treated waste stream. These BDAT list metals are thought to result from reaction of stainless steel process equipment with hydrogen chloride gas liberated from the process reactions. They must therefore be considered a part of the BDAT list selected constituents. Of these 12 detected BDAT list constituents, EPA has determined that all are treatable.

The constituents identified as major treatable constituents of K015 waste are toluene, anthracene, benzal chloride, benzo(b and/or k) fluoranthene, phenanthrene, and several metals (i.e., antimony, arsenic, barium, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc). Concentration data from the testing of K015 waste for these constituents are summarized in Table 6-2. The table shows concentrations detected in the untreated waste, as well as those in the treated waste.

6.2 Determination of Significant Treatment from BDAT

The next step in selecting the constituents to be regulated is to eliminate those identified constituents in the waste that cannot be significantly treated by the technologies designated as BDAT.

Having identified the major treatable BDAT list constituents present in the waste, EPA compared the analytical data to determine whether the

constituent concentration was reduced significantly from the untreated to the treated waste. For constituents present in the treated waste but not detected in the untreated waste, it was assumed that the constituent was present in the untreated waste at or near the detection limit. This assumption was based on the likelihood that the constituents would be masked by other constituents in the untreated waste.

If the concentration of a major treatable constituent is not reduced significantly by treatment deemed BDAT, the Agency eliminates the constituent from the list of identified constituents to be considered as regulated unless the concentration in the treated waste is high. Table 6-3 presents those BDAT list organic constituents determined by EPA to be treatable by liquid injection incineration. This technology would thus significantly reduce these concentrations. Those organic constituents that were not detected in the treated or untreated waste are not deemed treatable. They are therefore not considered for regulation because (1) the currently available analytical methods and recommended procedures are inadequate for these constituents and thus are considered unreliable; (2) the constituents, if present, are likely to be at low-level concentrations; or (3) it is assumed that the majority of these constituents are treated, if present at low levels, along with the treatable organic BDAT list constituents determined by EPA during the liquid injection incineration. As shown in Table 6-3, all identified organic constituents in K015 waste were significantly treated by liquid injection incineration.

BDAT list metals were found at high concentrations in the scrubber water residual. In such a case, treatment standards may be established for that constituent using some other demonstrated and available technology on a matrix similar to the treated residual. As discussed in Section 6.1, liquid injection incineration of K015 waste was not expected to treat metals, but metals were found in the treated wastewater. Chromium and nickel were present in the treated waste at the highest concentrations. In addition, these two BDAT list metals were present in concentrations for which treatment has been demonstrated by chromium reduction and chemical precipitation. The Agency believes that treatment of chromium and nickel will result in treatment of the other detected metals, since they are present at considerably lower concentrations.

6.3 Selection of Regulated Constituents

In summary, EPA has selected five BDAT organic constituents, toluene, anthracene, benzal chloride, benzo(b and/or k)fluoranthene, and phenanthrene, and two metal constituents, chromium and nickel, as the regulated constituents for K015 wastewaters.

Table 6-1 Status of BDAT List Constituent Presence
in Untreated K015 Waste

BDAT reference no.	Constituent	Detection status ^a	Believed to be present
<u>Volatile organics</u>			
222.	Acetone	ND	
1.	Acetonitrile	ND	
2.	Acrolein	ND	
3.	Acrylonitrile	ND	
4.	Benzene	ND	
5.	Bromodichloromethane	ND	
6.	Bromomethane	ND	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	ND	
8.	Carbon disulfide	ND	
9.	Chlorobenzene	ND	
10.	2-Chloro-1,3-butadiene	ND	
11.	Chlorodibromomethane	ND	
12.	Chloroethane	ND	
13.	2-Chloroethyl vinyl ether	ND	
14.	Chloroform	ND	
15.	Chloromethane	ND	
16.	3-Chloropropene	ND	
17.	1,2-Dibromo-3-chloropropane	ND	
18.	1,2-Dibromoethane	ND	
19.	Dibromomethane	ND	
20.	trans-1,4-Dichloro-2-butene	ND	
21.	Dichlorodifluoromethane	ND	
22.	1,1-Dichloroethane	ND	
23.	1,2-Dichloroethane	ND	
24.	1,1-Dichloroethylene	ND	
25.	trans-1,2-Dichloroethene	ND	
26.	1,2-Dichloropropane	ND	
27.	trans-1,3-Dichloropropene	ND	
28.	cis-1,3-Dichloropropene	ND	
29.	1,4-Dioxane	ND	
224.	2-Ethoxyethanol	NA	
225.	Ethyl acetate	ND	
226.	Ethyl benzene	ND	
30.	Ethyl cyanide	ND	
227.	Ethyl ether	ND	
31.	Ethyl methacrylate	ND	
214.	Ethylene oxide	ND	
32.	Iodomethane	ND	
33.	Isobutyl alcohol	NA	
228.	Methanol	NA	
34.	Methyl ethyl ketone	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status ^a	Believed to be present
<u>Volatile organics (continued)</u>			
229.	Methyl isobutyl ketone	ND	
35.	Methyl methacrylate	ND	
37.	Methacrylonitrile	ND	
38.	Methylene chloride	ND	
230.	2-Nitropropane	NA	
39.	Pyridine	ND	
40.	1,1,1,2-Tetrachloroethane	ND	
41.	1,1,2,2-Tetrachloroethane	ND	
42.	Tetrachloroethene	ND	
43.	Toluene	ND	Y
44.	Tribromomethane	ND	
45.	1,1,1-Trichloroethane	ND	
46.	1,1,2-Trichloroethane	ND	
47.	Trichloroethene	ND	
48.	Trichloromonofluoromethane	ND	
49.	1,2,3-Trichloropropane	ND	
231.	1,1,2-Trichloro-1,2,2- trifluoroethane	NA	
50.	Vinyl chloride	ND	
215.	1,2-Xylene	ND	
216.	1,3-Xylene	ND	
217.	1,4-Xylene	ND	
<u>Semivolatile organics</u>			
51.	Acenaphthalene	ND	
52.	Acenaphthene	ND	
53.	Acetophenone	ND	
54.	2-Acetylaminofluorene	ND	
55.	4-Aminobiphenyl	ND	
56.	Aniline	ND	
57.	Anthracene	ND	Y
58.	Aramite	ND	
59.	Benz(a)anthracene	ND	
218.	Benzal chloride	880,000-1,100,000	
60.	Benzenethiol	ND	
61.	Deleted		
62.	Benzo(a)pyrene	ND	
63.	Benzo(b)fluoranthene	ND	Y
64.	Benzo(ghi)perylene	ND	
65.	Benzo(k)fluoranthene	ND	Y
66.	p-Benzoquinone	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status ^a	Believed to be present
<u>Semivolatile organics (continued)</u>			
67.	Bis(2-chloroethoxy)methane	ND	
68.	Bis(2-chloroethyl)ether	ND	
69.	Bis(2-chloroisopropyl)ether	ND	
70.	Bis(2-ethylhexyl)phthalate	ND	
71.	4-Bromophenyl phenyl ether	ND	
72.	Butyl benzyl phthalate	ND	
73.	2-sec-Butyl-4,6-dinitrophenol	ND	
74.	p-Chloroaniline	ND	
75.	Chlorobenzilate	ND	
76.	p-Chloro-m-cresol	ND	
77.	2-Chloronaphthalene	ND	
78.	2-Chlorophenol	ND	
79.	3-Chloropropionitrile	ND	
80.	Chrysene	ND	
81.	ortho-Cresol	ND	
82.	para-Cresol	ND	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	ND	
84.	Dibenzo(a,e)pyrene	ND	
85.	Dibenzo(a,i)pyrene	ND	
86.	m-Dichlorobenzene	ND	
87.	o-Dichlorobenzene	ND	
88.	p-Dichlorobenzene	ND	
89.	3,3'-Dichlorobenzidine	ND	
90.	2,4-Dichlorophenol	ND	
91.	2,6-Dichlorophenol	ND	
92.	Diethyl phthalate	ND	
93.	3,3'-Dimethoxybenzidine	ND	
94.	p-Dimethylaminoazobenzene	ND	
95.	3,3'-Dimethylbenzidine	ND	
96.	2,4-Dimethylphenol	ND	
97.	Dimethyl phthalate	ND	
98.	Di-n-butyl phthalate	ND	
99.	1,4-Dinitrobenzene	ND	
100.	4,6-Dinitro-o-cresol	ND	
101.	2,4-Dinitrophenol	ND	
102.	2,4-Dinitrotoluene	ND	
103.	2,6-Dinitrotoluene	ND	
104.	Di-n-octyl phthalate	ND	
105.	Di-n-propylnitrosamine	ND	
106.	Diphenylamine	ND	
219.	Diphenylnitrosamine	ND	

Table 6-1 . (continued)

BDAT reference no.	Constituent	Detection status ^a	Believed to be present
<u>Semivolatile organics</u> (continued)			
107.	1,2-Diphenylhydrazine	ND	
108.	Fluoranthene	ND	
109.	Fluorene	ND	
110.	Hexachlorobenzene	ND	
111.	Hexachlorobutadiene	ND	
112.	Hexachlorocyclopentadiene	ND	
113.	Hexachloroethane	ND	
114.	Hexachlorophene	ND	
115.	Hexachloropropene	ND	
116.	Indeno(1,2,3-cd)pyrene	ND	
117.	Isosafrole	ND	
118.	Methapyrilene	ND	
119.	3-Methylcholanthrene	ND	
120.	4,4'-Methylenebis (2-chloroaniline)	ND	
36.	Methyl methanesulfonate	ND	
121.	Naphthalene	ND	
122.	1,4-Naphthoquinone	ND	
123.	1-Naphthylamine	ND	
124.	2-Naphthylamine	ND	
125.	p-Nitroaniline	ND	
126.	Nitrobenzene	ND	
127.	4-Nitrophenol	ND	
128.	N-Nitrosodi-n-butylamine	ND	
129.	N-Nitrosodiethylamine	ND	
130.	N-Nitrosodimethylamine	ND	
131.	N-Nitrosomethylethylamine	ND	
132.	N-Nitrosomorpholine	ND	
133.	N-Nitrosopiperidine	ND	
134.	N-Nitrosopyrrolidine	ND	
135.	5-Nitro-o-toluidine	ND	
136.	Pentachlorobenzene	ND	
137.	Pentachloroethane	ND	
138.	Pentachloronitrobenzene	ND	
139.	Pentachlorophenol	ND	
140.	Phenacetin	ND	
141.	Phenanthrene	ND	
142.	Phenol	ND	
220.	Phthalic anhydride	NA	
143.	2-Picoline	ND	
144.	Pronamide	ND	
145.	Pyrene	ND	
146.	Resorcinol	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection Status ^a	Believed to be present
<u>Semivolatile Organics</u> (continued)			
147.	Safrole	NO	
148.	1,2,4,5-Tetrachlorobenzene	NO	
149.	2,3,4,6-Tetrachlorophenol	NO	
150.	1,2,4-Trichlorobenzene	NO	
151.	2,4,5-Trichlorophenol	NO	
152.	2,4,6-Trichlorophenol	NO	
153.	Tris(2,3-dibromopropyl) phosphate	NO	
<u>Metals^b</u>			
154.	Antimony	NA	Y
155.	Arsenic	NA	Y
156.	Barium	NA	Y
157.	Beryllium	NA	
158.	Cadmium	NA	
159.	Chromium (total)	NA	Y
221.	Chromium (hexavalent)	NA	
160.	Copper	NA	Y
161.	Lead	NA	Y
162.	Mercury	NA	Y
163.	Nickel	NA	Y
164.	Selenium	NA	Y
165.	Silver	NA	Y
166.	Thallium	NA	
167.	Vanadium	NA	Y
168.	Zinc	NA	Y
<u>Inorganics other than metals</u>			
169.	Cyanide	NA	
170.	Fluoride	NA	
171.	Sulfide	NA	
<u>Organochlorine pesticides</u>			
172.	Aldrin	NA	
173.	alpha-BHC	NA	
174.	beta-BHC	NA	
175.	delta-BHC	NA	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection Status ^a	Believed to be present
<u>Organochlorine pesticides</u> (continued)			
176.	gamma-BHC	NA	
177.	Chlordane	NA	
178.	DDD	NA	
179.	DDE	NA	
180.	DDT	NA	
181.	Dieldrin	NA	
182.	Endosulfan I	NA	
183.	Endosulfan II	NA	
184.	Endrin	NA	
185.	Endrin aldehyde	NA	
186.	Heptachlor	NA	
187.	Heptachlor epoxide	NA	
188.	Isodrin	NA	
189.	Kepone	NA	
190.	Methoxychlor	NA	
191.	Toxaphene	NA	
<u>Phenoxyacetic acid herbicides</u>			
192.	2,4-Dichlorophenoxyacetic acid	ND	
193.	Silvex	ND	
194.	2,4,5-T	ND	
<u>Organophosphorous insecticides</u>			
195.	Disulfoton	ND	
196.	Famphur	ND	
197.	Methyl parathion	ND	
198.	Parathion	ND	
199.	Phorate	ND	
<u>PCBs</u>			
200.	Aroclor 1016	NA	
201.	Aroclor 1221	NA	
202.	Aroclor 1232	NA	
203.	Aroclor 1242	NA	
204.	Aroclor 1248	NA	
205.	Aroclor 1254	NA	
206.	Aroclor 1260	NA	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection Status ^a	Believed to be present
<u>Dioxins and furans</u>			
207.	Hexachlorodibenzo-p-dioxins	NA	
208.	Hexachlorodibenzofurans	NA	
209.	Pentachlorodibenzo-p-dioxins	NA	
210.	Pentachlorodibenzofurans	NA	
211.	Tetrachlorodibenzo-p-dioxins	NA	
212.	Tetrachlorodibenzofurans	NA	
213.	2,3,7,8-Tetrachlorodibenzo- p-dioxin	NA	

ND = Not detected.

NA = Not analyzed.

X = Believed to be present based on engineering analysis of waste generating process.

Y = Believed to be present based on detection in treated residuals.

^aIf detected, concentrations are shown; units are mg/kg.

^bBDAT list metals were not analyzed in the untreated waste.

Table 6-2 K015 Waste Constituents with Treatable Concentrations

BDAT number	Constituent	CAS number	Concentration in untreated waste (mg/kg)	Concentration in treated waste (mg/l)
43	Toluene	108-88-3	<10	0.015-0.059
57	Anthracene	120-12-7	<5,000	<0.050-0.210
218	Benzal chloride	98-87-3	910,000-1,100,000	<0.050-0.094
63 and/or 65	Benzo (b and/or k) fluoranthene	205-99-2/ 207-08-9	<5,000	<0.050-0.096
141	Phenanthrene	85-01-8	<5,000	<0.050-0.058
154	Antimony	7440-36-0	NA	<0.120-0.160
155	Arsenic	7440-38-2	NA	0.100-0.530
156	Barium	7440-39-3	NA	0.110-0.530
159	Chromium	7440-47-32	NA	4.0-34
160	Copper	7440-50-8	NA	0.580-0.35
161	Lead	7439-92-1	NA	0.060-0.300
162	Mercury	7439-97-6	NA	<0.0025-0.06
163	Nickel	7440-02-0	NA	2.2-25
164	Selenium	7782-49-2	NA	0.06-0.90
165	Silver	7440-22-4	NA	<0.035-0.300
167	Vanadium	7440-62-2	NA	0.050-0.390
168	Zinc	7440-66-6	NA	0.110-0.930

NA = Not analyzed in the untreated waste. See Section 6.1.

Table 6-3 Major Constituent Concentration Data

Major constituent	Concentration (accuracy-corrected concentration) ^a									Correction factor
	Untreated waste (mg/kg)			Treated waste (mg/l)						
	Sample set			Sample set						
	#1	#2	#3	#1	#2	#3	#1	#2	#3	
<u>Volatile organics</u>										
Toluene	<10	<10	<10	0.059	(0.059)	0.030	(0.030)	0.015	(0.015)	1.00
<u>Semivolatile organics</u>										
Anthracene	<5,000	<5,000	<5,000	<0.050	(<0.0986)	0.068	(0.134)	0.210	(0.414)	1.97
Benzal chloride	930,000	910,000	1,100,000	<0.050	(<0.0986)	0.068	(0.130)	0.094	(0.185)	1.97
Benzo(b and/or k)- fluoranthene	<5,000	<5,000	<5,000	<0.050	(<0.0986)	0.050	(<0.0986)	0.096	(0.189)	1.97
Phenanthrene	<5,000	<5,000	<5,000	<0.050	(<0.0986)	0.058	(0.114)	0.110	(0.217)	1.97
<u>Metals^b</u>										
Antimony	-	-	-	<0.12	(<0.250)	0.120	(0.250)	0.16	(0.340)	2.13 ^c
Arsenic	-	-	-	0.25	(0.260)	0.10	(0.100)	0.53	(0.540)	1.02
Barium	-	-	-	0.11	(0.150)	0.25	(0.330)	0.55	(0.720)	1.32
Chromium	-	-	-	4.0	(5.0)	18	(23)	34	(44)	1.28
Copper	-	-	-	0.58	(0.660)	1.6	(1.82)	3.5	(3.98)	1.14
Mercury	-	-	-	0.005	(0.005)	<0.0025	(<0.0025)	0.06	(0.060)	1.00
Nickel	-	-	-	2.2	(2.9)	11	(14.5)	25	(32.9)	1.32
Lead	-	-	-	0.06	(0.130)	0.24	(0.510)	0.30	(0.640)	2.13
Selenium	-	-	-	0.06	(0.080)	0.09	(0.130)	0.06	(0.080)	1.39
Silver	-	-	-	0.13	(0.160)	0.30	(0.370)	<0.035	(<0.043)	1.23
Vanadium	-	-	-	0.05	(0.066)	0.17	(0.220)	0.390	(0.510)	1.32
Zinc	-	-	-	0.11	(0.130)	0.75	(0.850)	0.93	(1.05)	1.14

^aThe data in parentheses have been adjusted for accuracy using the correction factors provided.

^bAs stated in Section 4, metals were not analyzed in the untreated waste.

^cThe wastewater matrix spike was not analyzed for antimony; accuracy-corrected values were calculated using an assumed correction factor of 2.13. (See Appendix B.)

7. CALCULATION OF BDAT TREATMENT STANDARDS

This section presents the calculation of the actual treatment standards for the regulated constituents determined in Section 6. EPA has three sets of untreated and treated data from one facility for treatment of K015 using liquid injection incineration. EPA also has 11 data sets for treatment of metal-bearing wastewaters by chromium reduction and chemical precipitation. As discussed in Section 1, the following steps were taken to derive the BDAT treatment standards for K015 wastewaters.

The Agency evaluated the three data sets collected from the liquid injection incineration treatment system to determine whether any of the data represented poor design or poor operation of the treatment system. The available data show that all three data sets do not represent poor design or poor operation. All three data sets for liquid injection incineration are used for establishing treatment standards for regulation of the BDAT list organic constituents in K015 wastewaters.

For the regulated BDAT list metal constituents chromium and nickel, treatment data were transferred from Envirite. The design and operating data were examined and indicated that the system was well designed and well operated. However, recovery values were not available for metal spikes and metal spike duplicating from the treatment data collected at Envirite. The recovery data used to correct the nickel and chromium data were transferred from the Onsite Engineering Report for Horsehead Resource Development Company for K061. This was determined to be the appropriate source for recovery data for BDAT list metals in wastewaters.

Accuracy-corrected constituent concentrations were calculated for all BDAT list constituents. An arithmetic average concentration level and a variability factor were determined for each BDAT list constituent regulated in this waste. The variability factor represents the variability inherent in the treatment process and the sampling and analytical methods. Variability factors are calculated based on the treatment data for each of the regulated constituents. The general methodology for calculating variability factors is presented in Appendix A.

The BDAT treatment standard for each constituent regulated in this rulemaking was determined by multiplying the average accuracy-corrected total composition by the appropriate variability factor. The treatment standards for the organic constituents are shown in Table 7-1. The calculation of the treatment standards for chromium and nickel is presented in Table 7-2.

Table 7-1 Calculation of BDAT Treatment Standards for
Regulated Organic Constituents in K015 Wastewaters

Constituent	<u>Accuracy-corrected concentration (mg/l)</u>			Average treated waste concentration (mg/l)	Variability factor (VF)	Treatment standard (average x VF)
	Sample set #1	Sample set #2	Sample set #3			
Toluene	0.059	0.030	0.015	0.035	4.26	0.15
Anthracene	<0.099	0.134	0.414	0.216	4.15	1.0
Benzal chloride	<0.099	0.130	0.185	0.138	2.02	0.28
Benzo(b and/or k) fluoranthene	<0.099	<0.099	0.189	0.129	2.28	0.29
Phenanthrene	<0.099	0.114	0.217	0.107	2.50	0.27

Table 7-2 Treated Standards for K015 Wastewater Regulated Metal Constituents
Treated by Chromium Reduction and Chemical Precipitation

Constituent	Correction factor	Accuracy-corrected concentration (mg/l)											Average (mg/l)	Variability factor (VF)	Treatment standard Avg * VF)
		Sample Set #													
		1	2	3	4	5	6	7	8	9	10	11			
<u>BDAT Metals</u>															
Chromium	1.47	0.176	0.176	0.294	0.147	0.162	0.147	0.176	0.221	0.147	0.176	0.264	0.19	1.69	0.32
Nickel	1.08	0.355	0.355	0.355	0.355	0.333	0.355	0.430	0.387	0.355	0.355	0.419	0.37	1.20	0.44

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APPENDIX A
STATISTICAL METHODS

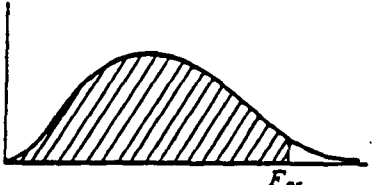
A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

<p>95th PERCENTILE VALUES FOR THE F DISTRIBUTION</p> <p>n_1 = degrees of freedom for numerator n_2 = degrees of freedom for denominator (shaded area = .95)</p>		
---	--	---

$n_1 \backslash n_2$	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

- (i) All data are natural logtransformed.
- (ii) The sum of the data points for each data set is computed (T_i).
- (iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^k T_i \right)^2}{N} \right]$$

where:

- k = number of treatment technologies
- n_i = number of data points for technology i
- N = number of data points for all technologies
- T_i = sum of natural logtransformed data points for each technology.

- (iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^k \sum_{j=1}^{n_i} x_{i,j}^2 \right] - \sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right)$$

where:

- $x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by $k-1$. For SSW, the degree of freedom is given by $N-k$.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and

$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	$k-1$	SSB	$MSB = SSB/k-1$	MSB/MSW
Within	$N-k$	SSW	$MSW = SSW/N-k$	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

<u>Steam stripping</u>				<u>Biological treatment</u>			
Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$[\ln(\text{effluent})]^2$	Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$[\ln(\text{effluent})]^2$
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-	-	23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-		2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^k T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^k \sum_{j=1}^{n_i} x_{i,j}^2 \right] - \sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

$$F = MSB/MSW$$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$$n_1 = 10, n_2 = 5, N = 15, k = 2, T_1 = 23.18, T_2 = 12.46, T = 35.64, T^2 = 1270.21$$

$$T_1^2 = 537.31 \quad T_2^2 = 155.25$$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5} \right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5} \right) = 0.77$$

$$MSB = 0.10/1 = 0.10$$

$$MSW = 0.77/13 = 0.06$$

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

<u>Steam stripping</u>				<u>Biological treatment</u>			
Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$[\ln(\text{effluent})]^2$	Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$[\ln(\text{effluent})]^2$
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum:							
-	-	26.14	72.92	-	-	16.59	39.52
Sample Size:							
10	10	10	-	7	7	7	-
Mean:							
2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:							
3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:							
-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^k T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^k \sum_{j=1}^{n_i} x_{i,j}^2 \right] - \sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 2 (Continued)

$$F = MSB/MSW$$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

x_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$$N_1 = 10, N_2 = 7, N = 17, k = 2, T_1 = 26.14, T_2 = 16.59, T = 42.73, T^2 = 1825.85, T_1^2 = 683.30,$$

$$T_2^2 = 275.23$$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7} \right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7} \right) = 4.79$$

$$MSB = 0.25/1 = 0.25$$

$$MSW = 4.79/15 = 0.32$$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

<u>Activated sludge followed by carbon adsorption</u>				<u>Biological treatment</u>			
Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$[\ln(\text{effluent})]^2$	Influent ($\mu\text{g/l}$)	Effluent ($\mu\text{g/l}$)	$\ln(\text{effluent})$	$\ln[(\text{effluent})]^2$
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	-
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^k T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^k \sum_{j=1}^{n_i} x_{i,j}^2 \right] - \sum_{i=1}^k \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

$$F = MSB/MSW$$

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$$N_1 = 4, N_2 = 7, N = 11, k = 2, T_1 = 14.49, T_2 = 38.90, T = 53.39, T^2 = 2850.49, T_1^2 = 209.96$$

$$T_2^2 = 1513.21$$

$$SSB = \left(\frac{209.96}{4} + \frac{1513.21}{7} \right) - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left(\frac{209.96}{4} + \frac{1513.21}{7} \right) = 14.88$$

$$MSB = 9.52/1 = 9.52$$

$$MSW = 14.88/9 = 1.65$$

$$F = 9.52/1.65 = 5.77$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{\text{Mean}}$$

where:

- VF = estimate of daily maximum variability factor determined from a sample population of daily data;
- C₉₉ = estimate of performance values for which 99 percent of the daily observations will be below. C₉₉ is calculated using the following equation: $C_{99} = \text{Exp}(y + 2.33 S_y)$ where y and S_y are the mean and standard deviation, respectively, of the logtransformed data; and
- Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are

distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{\text{Mean}}. \quad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \text{Exp} (\mu + 2.33\sigma) \quad (2)$$

$$\text{Mean} = \text{Exp} (\mu + 0.5\sigma^2). \quad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \text{Exp} (2.33 \sigma - 0.5\sigma^2). \quad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations

that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.
- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to $\ln(UL)$ and a lower limit equal to $\ln(LL)$.
- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

$$\begin{aligned}\sigma &= [\ln(UL) - \ln(LL)] / [(2)(2.33)] \\ &= [\ln(UL/LL)] / 4.66.\end{aligned}\tag{5}$$

(Note that when $LL = (0.1)(UL)$ as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494$.)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8.\tag{6}$$

APPENDIX B
ANALYTICAL QA/QC

The methods used to analyze the constituents identified in Section 5 are presented in Table B-1. All methods are described in SW-846 Third Edition (EPA's Test Methods for Evaluating Solid Waste).

The accuracy determination for a constituent is based on matrix spike recovery values. The inverse of the recovery is the correction factor. An accuracy-corrected value is simply the analytical result multiplied by the correction factor as shown in the following example:

$$\begin{array}{rclcl} \text{Analytical Result} & & \text{Correction Factor} & & \text{Accuracy-Corrected Value} \\ 0.13 \text{ mg/l} & \times & 1.23 & = & 0.16 \text{ mg/l.} \end{array}$$

Only one of the organic compounds identified as a major constituent in K015 wastewaters, toluene, served as a spiking component. Its recovery was 100 percent. Thus, the detected values and accuracy-corrected values for toluene are identical. For the remaining organics in the wastewaters (all semivolatiles), the recovery value for each was taken to be the average of the recoveries for similar compounds. The identified semivolatiles were all base neutral compounds; thus, the average recovery for the base neutral spiking compounds was used as a recovery value. The matrix spike data for the base neutral semivolatile compounds in K015 wastewaters are presented in Table B-2. As shown, the average recovery is 50.7 percent, corresponding to a correction factor of 1.97.

For each metal compound identified as a major constituent, the data were adjusted using the lower of the matrix spike and matrix spike duplicate recoveries for that compound, except in the case of antimony. Because the wastewater matrix spike was not analyzed for antimony, the data were adjusted using the lowest recovery of all major metal constituents in the waste (i.e., for lead). Table B-3 summarizes the major constituents in the K015 wastewater, their recovery values, and the respective correction factors used to obtain the accuracy-corrected concentrations displayed on Table 5-3.

Table B-1 Analytical Methods

Analysis/methods	Method
<u>Volatile Organics</u>	
Purge-and-trap	5030
Gas chromatography/mass spectrometry for volatile organics	8240
<u>Semivolatile Organics</u>	
Continuous liquid-liquid extraction (treated waste)	3520
Soxhlet extraction (untreated waste)	3540
Gas chromatography/mass spectrometry for semi-volatile organics: Capillary Column Technique	8270
<u>Metals</u>	
Digestion	
Aqueous liquids analyzed by ICP	3010
Aqueous liquids analyzed by graphite furnace	3020
Inductively coupled plasma atomic emission spectroscopy (antimony/barium/chromium/copper/nickel/silver/vanadium/zinc)	6010
Arsenic (atomic absorption, furnace technique)	7060
Selenium (atomic absorption, furnace technique)	7740
Mercury in solid or semisolid waste (manual cold-vapor technique)	7471
Lead (atomic absorption, furnace technique)	7421

Reference: USEPA 1986b.

Table B-2 Base Neutral Matrix Spike Data for K015 Wastewater

Compound	Percent recovery	
	Matrix spike	Matrix spike duplicate
1,4-Dichlorobenzene	40	37
N-nitrosodi-n-propylamine	75	65
1,2,4-Trichlorobenzene	37	35
Acenaphthene	76	80
2,4-Dinitrotoluene	25	25
Pyrene	52	62
Average:	50.83	50.66
Combined averages:	50.7	

Table B-3 Metal Matrix Spike Data for K015 Wastewater

Compound	Lowest percent recovery	Correction factor
Silver	81	1.23
Arsenic	98	1.02
Barium	76	1.32
Beryllium	77	1.30
Chromium	78	1.28
Copper	88	1.14
Mercury	100	1.00
Nickel	76	1.32
Lead	47	2.13
Antimony	47 ^a	2.13 ^a
Selenium	72	1.39
Vanadium	76	1.32
Zinc	88	1.14

^aThese are assumed values. See text.

APPENDIX C

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure C-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed into a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

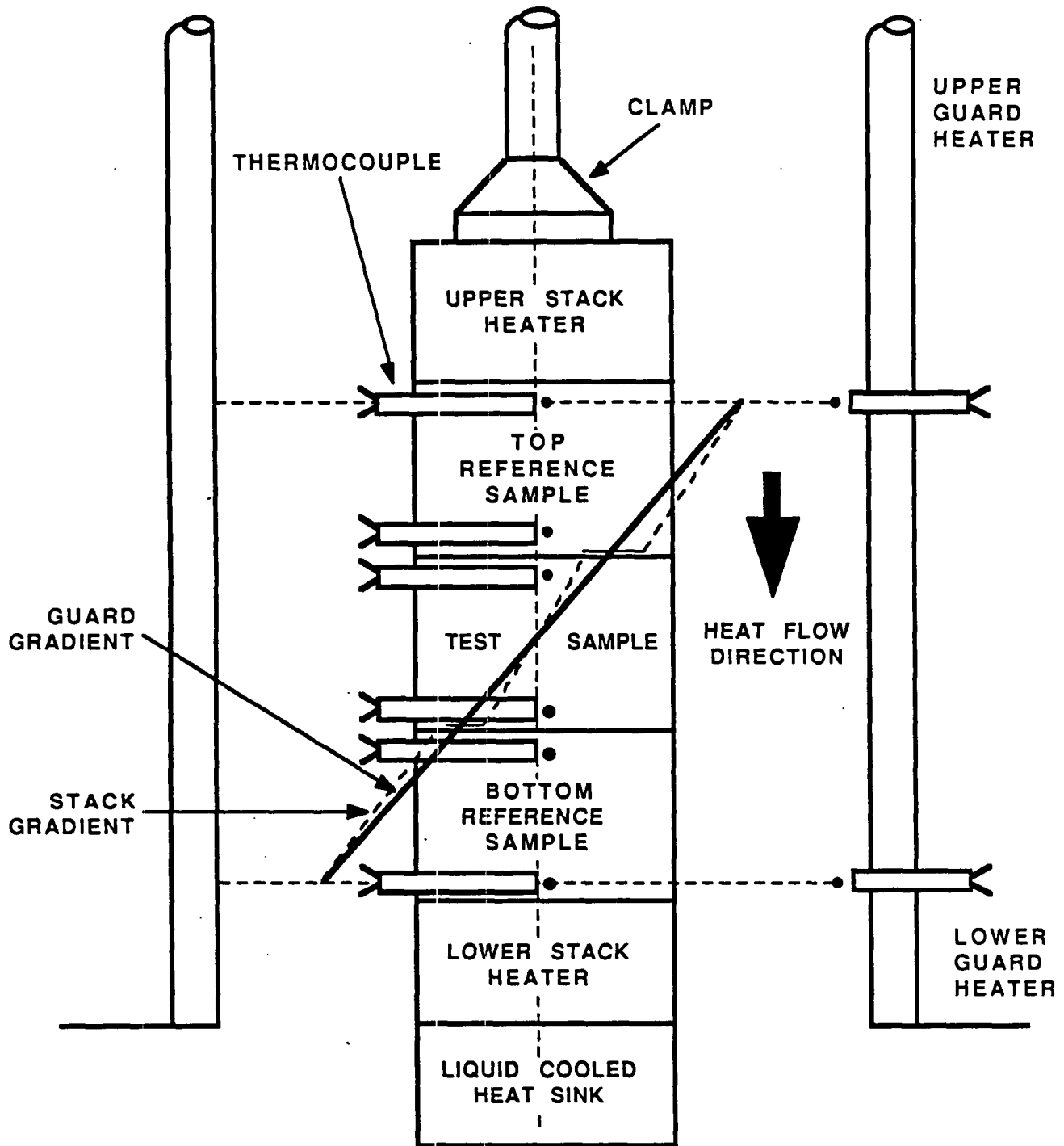


FIGURE C-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The stack is clamped with a reproducible load to ensure intimate contact between the components. To produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack, and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady-state method of measuring thermal conductivity. When equilibrium is reached, the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top} (dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom} (dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference, while bottom refers to the lower reference. If the heat were confined to flow down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2.$$

The sample thermal conductivity is then found from

$$\lambda_{sample} = Q/(dT/dx)_{sample}.$$