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Technology Transfer

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Seminar Publication

Permitting Hazardous Waste Incinerators

Seminars for Hazardous Waste Incinerator Permit Writers, Inspectors, and Operators

October 16-17, 1986
Rosemont, Illinois

October 28-29, 1986
Dallas, Texas

November 13-14, 1986
Atlanta, Georgia

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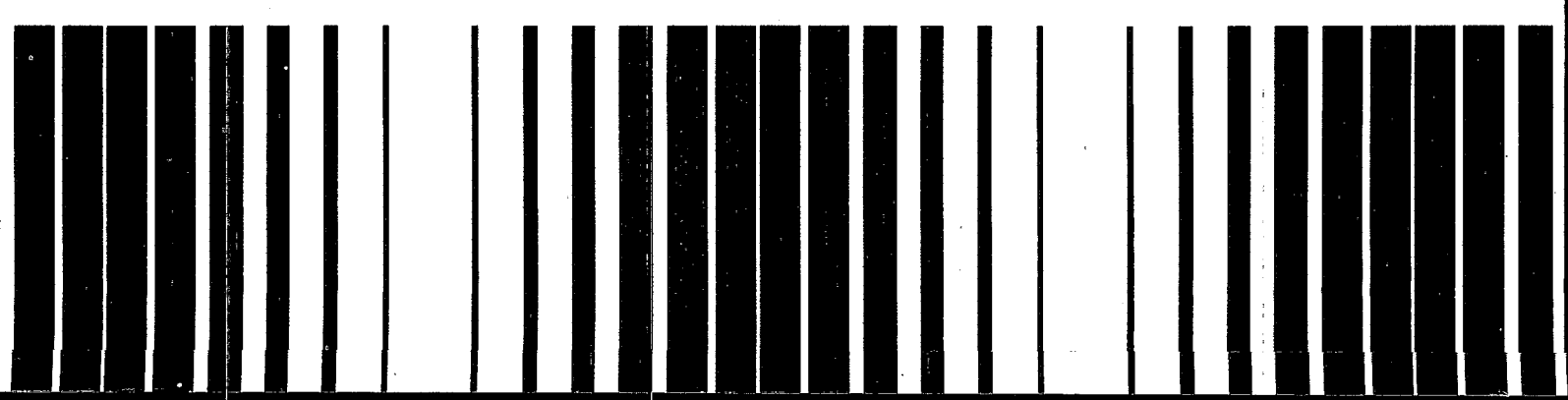

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Foreword

An estimated 233 existing incinerators in the U.S. will require RCRA hazardous waste permits by the statutory deadline of 1989. Although many incinerators have prepared Part B permit applications, only 25 have been fully permitted under RCRA. The large majority are continuing to operate under interim status and many new incinerators will also require permits.

The preparation, review, and approval of incinerator Part B applications is complex, time consuming, and expensive, averaging 1.2 years for new units and 2 years for existing ones. The principal obstacle in the Part B review process is the evaluation of the trial burn plan and data. Approximately 50 percent of the permit review process is spent evaluating this portion of the application. It is this information that ultimately demonstrates the ability of the incinerator to adequately destroy hazardous wastes and which forms the basis for establishing key permit conditions for operation of the incinerator.

This seminar series was designed to address the problems and issues that affect the issuance of hazardous waste incineration permits. In particular, the seminars were designed to improve the overall understanding of trial burn testing.

Papers presented by the seminar speakers are compiled within this Proceedings, and should be of value to those involved in the design, execution, reporting, and evaluation of trial burn tests. Those wishing additional information are urged to contact the authors or the EPA Project Officer, Mr. Norm Kulujian, Center for Environmental Research Information, Cincinnati, Ohio (513/569-7349).

Calvin O. Lawrence, Director
Center for Environmental Research Information

Abstract

Five two-day seminars on permitting hazardous waste incinerators were held in cities geographically central to those parts of the country that generate the most wastes and have the most existing incinerators. Over 800 people attended the five seminars, which began on October 16, 1986, and concluded December 5, 1986. The seminars reached both federal and State permit writers responsible for reviewing and approving Part B applications and establishing RCRA permit conditions, and owners/operators (or their engineering consultants) responsible for designing, conducting, and submitting trial burn test plans and reports.

The seminars were designed around a number of specific technology transfer objectives. Specifically, the seminars provided guidance on how to:

- Relate trial burn data to permit conditions.
- Design and execute trial burns and monitoring strategies.
- Ensure that quality assurance of trial burn data sets is conducted adequately.
- Identify deficiencies and their causes in trial burn designs and resulting data sets.
- Recognize variables in trial burn data and understand how to deal with them.
- Organize the trial burn section of a permit application in the most effective manner.

Emphasis was on typical shortcomings in trial-burn plans and how permit writers can interact with applicants to minimize the likelihood of deficiencies in data and misunderstandings in requirements.

This document is a compilation of papers written by each of the speakers detailing the information presented during each of the seminars.

Contents

Incineration Technology—State-of-the-Art Review

By

Joseph J. Santoleri
Four Nines, Inc.

Introduction

In the 1960's, much effort was expended on cleaning up the air and water. Air Quality and Water Quality Acts were being written and implemented in many States and communities. New products such as unleaded gasoline and water base paints were developed to help minimize pollution. Conversion from oils to natural gas for comfort and industrial heating was the normal practice.

In the 1970's, there was a sudden concern on how to safely dispose of hazardous wastes. Indiscriminate dumping of chemical wastes of all types had been going on since the birth of the chemical industry in the U.S.A. Land dumping, inadequate landfills, and dumping into rivers and oceans were the most economical ways to dispose of chemical hydrocarbon waste. Methods that would have eliminated wastes permanently were initially disregarded as being too costly.

However, many of the major chemical companies installed incinerator facilities on their own plant sites, not because it was the most economical method but because they realized that other methods of disposal would not be open to them. Now, in the 1980's we recognize that restrictions on chemical landfills will eliminate the casual small and underfinanced operator; ocean dumping will be a thing of the past, and deep well disposal will ultimately be phased out.

Incineration under proper control and application of the proper technology will provide the best, and in the long run, the most economical avenue to the total destruction of organic hazardous wastes.

Incineration Not a New Technology

Incineration is not a new technology. It has been used for many years. Some municipal incineration facilities were in operation more than 50 years. But because our air pollution laws were really the first group of environmental laws to affect the nation, incineration, especially in the municipal waste area, received a bad name. Therefore, incinerators, rather than being purchased and started up during the 1970's, were being closed because they could not meet current air pollution regulations. With the closure of many landfills, which many industry watchers are certain will occur, incineration will once again be restored to its rightful position in hazardous waste management. Industrial incinerators burning chemical wastes go back to the 1950's. The technologies involved in the incineration waste included:

1. LIQUID INJECTION systems to burn high heating value, easily combustible materials, many of which created acid gases that had to be removed by downstream scrubbing device.

2. The ROTARY KILN which was an outgrowth of the cement industry, rotary process driers and later municipal incineration was found to be a relatively simple and forgiving system for the types and varieties of wastes which it could handle.

3. The FLUID BED system came along in the 1960's and 1970's first to handle papermill wastes, then certain refinery wastes, and finally some chemical wastes, but the fluid bed had limitations as did all the rest. The most important was that it was expensive like the rotary kiln and economics could not justify its use.

4. The MULTIPLE HEARTH incinerator was not an incinerator at first; it was a device used for roasting ore from various metal mining and refining operations but it was applied to a rapidly growing market; that is disposal of sewage sludges. The multiple hearth thrived for a period during the 1960's and 1970's when air pollution regulations were not that stringent.

5. STARVED AIR or, as it is now called, the CONTROLLED AIR incinerator came along. It was basically a hearth-type system with an afterburner section which burned the incomplete products of combustion from the first stage. While these systems were small and modular, they were widely used during the 1970's for destruction of plant waste and some hazardous materials.

Liquid injection incinerators are the most common type. They represent 64% of all the hazardous waste incinerators in service. Most are off-shoots of liquid fuel burning design as used in boilers using the same techniques of atomization, air mixing and burning. These units may be designed to burn various types of waste liquors. These are completely organic, an aqueous waste with organics, or an aqueous waste with organics and

solids. Solids are usually dissolved in organics contained in the liquid wastes.

An organic that is considered most hazardous is one containing chlorine, often referred to as a chlorinated hydrocarbon. Many process industries, such as agricultural, pharmaceutical, refineries, etc., generate these chlorinated hydrocarbons. The chlorine tends to reduce the combustibility due to the lower heating value and also creates a fuel more difficult to burn. If improperly burned, the chlorinated materials tend to form soot. The products of combustion include hydrochloric acid gas as well as carbon dioxide, oxygen, nitrogen and water vapor. The corrosive nature of the fluid causes problems with nozzles, refractories and the downstream heat recovery and pollution control devices of an incinerator system. Systems are operated today which include the latest technology for the combustion and incineration systems (including materials of construction), as well as the heat recovery devices (waste heat boilers) and hyproduct recovery (acid recovery towers). Operating units with steam generation loads of 60,000 lb per hour are in service today.

For solids, sludges and materials that are not easily pumped, rotary kiln incinerators are used. Normally, these do not require pre-treatment of the wastes prior to feeding to the incinerator. Feed mechanism are belts, clam shells into a hopper, screw feeders, augers, as well as ram feeders. The kiln refractory must be able to withstand the shock of a drum loaded with solids or sludges sticking to the rotating inner diameter. Certain sludges, slurries and liquids are fed by positive displacement pumps to the incinerator chamber. Some may be injected by nozzles similar to the liquid injection units.

In the kiln, sufficient air is introduced to provide combustion of the highly volatile materials that also provide the energy needed to raise the solids to volatilization temperatures. Organic compounds that make up the solids are heated to volatilization temperatures releasing hydrocarbon gases, carbon monoxide, hydrogen, etc. Rotation, length, diameter and slope of the kiln determine the total residence time for the solids to permit complete volatilization of the hydrocarbon compounds. The inert ash in the waste is all that remains to be dropped into the ash collection system. The volatilized gases at temperatures of 1600-2000°F are exhausted into the afterburner chamber. Some kilns operate in a slagging mode which permits all metal compounds (drums, cans, etc.) to reach the molten stage. All ash is discharged into a hot tap to minimize the handling problems of distorted steel drums, steel strapping, etc.

The afterburner chamber is designed to operate with sufficient oxygen, temperature and mixing to convert all the hydrocarbons into carbon dioxide and water vapor. Halogenated compounds will be converted to the halogen hydride. Auxiliary fuel is fired into this chamber to provide the energy necessary to raise the exit temperatures to levels of 2000-2400°F. This fuel can be in the form of waste solvents, organics or other fuels with little or no ash content.

Of the other types described above, the starved air/ controlled air incinerator is the only one that is in wider use for hazardous waste than either the fluid bed or the multiple hearth. In this case, the starved air is used also for solid waste materials, sludges and slurries similar to the rotary kiln applications. A major difference is that the starved air operates under a reducing atmosphere in the primary chamber. The solids must be volatilized in the absence of sufficient oxygen. Typical operations are in the range of 60-70% of the air necessary for complete combustion. It is critical that the time in the primary chamber insures that the ash leaving the chamber has been devolatilized and is inert. This requires that sufficient exposure of the materials be accomplished by the multiple ram feeds that are utilized in this design. In this unit, the secondary chamber serves the same purpose as in the kiln secondary, in that complete oxidation of the volatilized vapors occur. The additional air required for the volatile gases is introduced at the juncture between the two chambers. It is important that turbulence and mixing be achieved in a very short time so that the residence time in the chambers serves to completely detoxify and oxidize the hazardous compounds. Both the fluid bed and multiple hearth have been used in many sewage sludge treatment plants. Applications of the fluid bed for hazardous waste have been few; however, there is a concerted effort to utilize this technology in the hazardous waste area due to the advantages of being able to handle the halogenated compounds, as well as sulfur-bearing compounds, with the neutralization occurring in the bed by using a limestone material. Advances to the concept of the fluid bed are being made and described below.

The multiple hearth has been utilized in the sewage sludge incineration industry as well as in the roasting and calcining application.

Emerging Technologies

When reviewing the last 50 years of incineration and perhaps the last 20 years of hazardous and chemical waste incineration, one might be tempted to say that we have made no advances in this time in the basic technology. To some degree this criticism is true because these major technologies are primarily used for incineration of hazardous waste today. It is encouraging, however, that there are some new ideas emanating from inquisitive minds throughout the industry. We are describing here some of these new ideas together with their advantages and disadvantages.

An off-shoot of the fluid bed technique by GA Technologies of San Diego, CA, utilizes a circulating fluid bed claiming higher gas velocites than the conventional fluid bed system, with the advantage of using lower calorific value in the waste. Another fluid bed technique developed by PEDCo Environmental in Cincinnati, OH, and continued development by Rollins Environmental Services, is the cascading bed incinerator. This is essentially a rotary kiln partially filled with a uniform size sand which is fluidized by the action of the mechanical lifters on the inside of the kiln's surface. The fluidizing agent passes through the kiln and is returned to the front

end through a unique inertial spiral system. Wastes fed into the kiln at the front end are mixed with the hot sand from the rear end of the kiln, thus conserving heat and reducing the amount of fuel required to sustain combustion. The ROTARY REACTOR as it is now known is unlined and is limited to a maximum temperature of about 1600°F.

A third system dependent upon uniform size feed is the Huber Advanced Electrical Reactor. While not a fluidized bed system, the incineration process is similar. Hazardous waste material of uniform size is dropped into a vertical porous carbon tube which has been heated externally by electric heaters and the annulus around the tube is slightly pressurized by nitrogen gas. The nitrogen gas passing through the porous tube is transparent to the radiation and prevents the waste particles from collecting on the tube wall. This system has the advantage of extremely high temperatures (in excess of 4000°F) and, therefore, extremely high destruction efficiences. The residence time in the Huber system can be extremely short due to the extremely high temperatures.

Two systems which differ from the fluid bed concept are the Penberthy Electromelt International System and the Rockwell International System, both of which use a molten matrix to achieve destruction. The Penberthy system is an electric glass furnace into which waste materials are fed. The high temperature of the glass furnace (2200°F) gives high DRE values. The resulting ash is trapped in the glass which is drawn from the furnace and solidified. The Rockwell system utilizes sodium carbonate in a molten form and injects both air and hazardous combustible waste into the melt. It is especially attractive for chlorianted wastes since the sodium carbonate reacts with the chlorine or hydrogen chloride that is formed during combustion. A third system of similar concept is the Arc Technology Process currently under development by Chemical Waste Management. This sealed pyrolytic system utilizes a direct current electric arc furnace with a molten steel bed maintained at temperatures near 3000°F into which hazardous material such as PCB contaminated capacitors can be fed. At these temperatures, the capacitors melt immediately and the PCBs pass through the electric arc plasma at ultra high temperatures and are destroyed. The gases formed from the destruction of the organic material pass up through a hollow electrode and then through a conventional treatment process. Scrubbed gases containing residual hydrogen are flared using conventional techniques. Only pilot-plant operations have been performed to date.

Another electrically heated incineration system is the Shirco Radiant Furnace. Materials to be incinerated are introduced on a traveling belt and exposed to the high temperatures of electric glow bars. The material must be prepared similar to that which is injected into the fluid bed. It is critical that the size be such that the depth of the material on the belt allows heat transfer through the entire depth. The material is fed through a hopper, screw feed or ram feed device onto the belt so that the incoming materials contact the hottest gases leaving the incineration chamber. As the material travels through the furnace and the volatile compounds are volatilized, heat is released from the reaction; the ash is discharged essentially inert. The gases generated in the incineration chamber are then drawn into a secondary combustion chamber where temperatures are increased from approximately 1500-1600°F up to 2000-2200°F. This is done either electrically or by using auxiliary fuel or waste fuels. The volatilized gases at this point are completely destroyed by incineration with the proper oxygen, mixing and residence time. The gases then pass through the air pollution control system and eventually into the induced draft fan and out the stack.

The last system described here is unique in that while a thermal system, it does not have any similarities to other destruction methods. It is deep well where the pressures and temperatures associated with deep well operation provide the destruction of the organic materials. It is the Vertical Tube Reactor supplied by Vertek Treatment Systems of Colorado. Diluted waste liquid is pumped into the inner annular space of concentric vertical tubes. These tubes are suspended in a conventionally drilled and cased well 5200 ft deep with a tubular heat exchanger running down the center. The waste stream and injected air flow down the tube and reach a peak natural pressure of the 1500 psig at the bottom due to the height and density of the fluid above. Actual combustion occurs while the waste substances are in a liquid state when sufficient air, temperature, pressure and organic content are present. During this oxidation process some heat is generated which then may be removed using the central heat exchanger. This offers the possibility of recovery of this heat for use at the surface. The diameter and length of the vertical tubes are designed to provide sufficient residence time so that the oxidation reaction can be completed and, in addition, the high length to diameter ratio allows extremely efficient counter flow heat exchange and mass transfer. The reactant products leave through the outer annular space, then flow into an air separation tank and into a settling tank. Here it is held for about 30 minutes, allowing time for the ash to settle out. The settled particles are pumped to the ash pits and the clarified liquid is returned to the biological process.

Conclusions

These processes are not all the processes available today for thermal treatment of hazardous wastes. No attempt has been made to closely evaluate the economics of these systems. It is obvious that some might not be economical under the present cost structure for the disposal of hazardous waste. This does not mean that they cannot become economical 5 or 10 years from now. It is important to recognize that there are other technologies being pursued which are widely different from those employed in current practice and one day in the near future these may be major thermal disposal methods.

Developing a Trial Burn Plan

By

Walter S. Smith
and
Tony Wong

The Resource Conservation and Recovery Act (RCRA) was designed to ensure that incineration facilities which treat hazardous wastes operate in an environmentally responsible manner. Under the requirements of RCRA, a trial burn must be conducted in order to obtain a finalized operating permit. A trial burn is a test which determines whether an incinerator is capable of meeting or exceeding RCRA performance standards. If the standards are met, then the trial burn should identify the operating conditions necessary to ensure the incinerator's ability to meet or exceed the performance standards throughout the life of the permit.

Development of the trial burn must incorporate interests of both the permit writer and the applicant. The permit writer wishes to obtain sufficient data necessary to establish the permit conditions. The applicant wishes to obtain a permit which allows the greatest flexibility of incinerator operating parameters set forth in the final permit. The areas of interest to be discussed, which allow the applicant and permit writer to achieve their goals, include understanding the problem, selecting a waste feed, choosing a principal organic hazardous constituent (POHC), determining operating conditions, choosing appropriate sampling methods, and obtaining representative samples (QA/QC). The purpose of the paper is to give an overview of what is required to develop a trial burn plan.

Understanding the Problem

The first thing to do before attempting any task is to identify the problem. For a hazardous waste incinerator, the problem is obtaining an operating permit by performing a trial burn which meets or exceeds the performance standards. These performance standards are:

1. 99.99% DRE of all designated POHCs,
2. 0.08 gr/DSCF of particulate emissions corrected to 7% oxygen, and
3. 4 lb/hr of hydrogen chloride emissions or a 99% removal efficiency.

A person experienced in the area of incineration must be available for consultation during the development of a trial burn plan. Specific incinerator limitations such as heat capacity, flow capacity, and residence time must be known. Understanding the incinerator and its limitations is a major step in the development of a trial burn plan. A classic example of not knowing an incinerator's capabilities occurred when a facility hired a consultant to develop the trial burn plan. A plan with several operating conditions was designed with the first condition having the lowest thermal input. It was determined during operation that the lowest thermal input was equal to the thermal capacity of the incinerator. It appears that the consultant did not have an adequate understanding of this incinerator and did not develop the trial burn in conjunction with the incinerator operators. He based his plan upon theory, not upon the years of experience of plant personnel.

When a trial burn is designed, decisions must be made concerning the needs of the facility. If the facility handles a large amount of wastes, then volume (throughput) may be important. For a commercial incinerator, the main objective may be the ability to handle a wide variety of wastes. If this is the case, then a POHC with one of the lowest heat of combustion values should be chosen. On the other hand, the concern could be high chlorine content, high ash content, or high BTU content. Whatever the situation, the factors most advantageous to the facility must be determined.

An important element in understanding the problem is often planning for the future. There is always the potential of expansion and the need to incinerate other waste materials. The need may arise to incinerate a new waste feed containing a hazardous constituent with a lower heat of combustion than the designated POHC used for the trial burn. If this is the case, another trial burn must be performed or the wastes must be shipped elsewhere for disposal. Either alternative requires additional expense. The choice of waste feeds, operating conditions, and designated POHCs should reflect future plans.

Selecting a Waste Feed

Three options are available when selecting a waste feed: using the normal plant waste, spiking the normal plant waste, or developing a contrived waste.

Using the normal plant waste during the trial burn offers a couple of obvious advantages. First of all, normal waste is readily available. This waste has been incinerated during interim status or is expected to be incinerated once the permit is obtained. This approach is also indicative of normal operation. Disadvantages include possible interferences by waste constituents other than the designated POHCs, which may complicate the chemical analysis of both the waste feed and the stack gas. More importantly, when normal plant waste is used, the facility is limited to testing only for the POHCs present in the waste. The permit, therefore, will be limited to burning only those POHCs with heats of combustion greater than, or equal to, the most difficult POHC to be incinerated in the waste.

Spiking a normal waste offers the same advantages of normal waste, but it also reduces the number of problem areas. An increase in the concentrations of the designated POHCs should increase the stack gas concentrations, therefore reducing the possible interferences associated with chemical analysis of the waste feed and stack gas. Another major advantage is the ability to broaden the number of hazardous constituents that will be allowed by the permit. For example, if the waste were spiked with carbon tetrachloride and a 99.99% DRE is achieved, the permit would allow the facility to incinerate nearly all of the Appendix VIII compounds. One potential disadvantage associated with incinerating normal wastes is the possible formation of products of incomplete combustion (PIC), which could be a designated POHC. Unfortunately, it is impossible to determine the effects of incineration on various wastes and the resulting products.

The use of artificial waste may simplify analytical difficulties by reducing interferences, create a waste which is difficult to burn, and offer a wide range of possibilities. A wide range can be interpreted as a large variation in POHCs, heat content, chlorides, or ash content. A major deficiency of this approach is that the artificial waste will not have the same physical composition as the normal waste. For example, when an artificial waste with an ash content comparable to the normal waste was used during one trial burn, the particulate results from the trial burn exceeded the standards by a factor of 10. In contrast, particulate results from incineration of normal wastes under the same operating parameters showed concentrations below the standards. In this situation burning the contrived waste was not indicative of normal operations.

Choosing a POHC

When choosing a POHC for the trial burn, an analysis of the normal waste feed is performed to determine the hazardous constituents of significant concentrations. The present guideline for consideration of a POHC to be of significant concentration in the waste is 100 ppm. However, if the compound is highly toxic, a concentration under 100 ppm can be considered significant.

In addition to identification and quantification of the hazardous constituents, analyses must be performed to measure viscosity, heating value, organically bound chlorine, and ash content. Viscosity measurements provide the permit writer with information necessary to judge the adequacy of liquid waste delivery systems. Heating value of the waste is used to determine and maintain operating conditions and may be used to establish permit conditions for allowable variations in waste content. The ash content is measured to assess particulate removal requirements of the control system and to determine if the ash handling capability of the system is sufficient.

From the analysis, the designated POHCs can be chosen by considering two basic factors: (1) the concentrations of each organic hazardous constituent in the waste feed, and (2) the rank of incinerability. Generally, the hazardous constituent of greatest concentration is chosen as one of the designated POHCs. Another POHC should be chosen based upon the rank of incinerability. To select the POHCs for a given waste, the permit writer should align the hazardous constituents and their concentrations in order of increasing incinerability. The constituent with the lowest heat of combustion value (considered the least incinerable), as well as the most abundant constituent, should be designated POHCs. Based upon the rank of incinerability, only one POHC need be designated. However, the correlation between the heat of combustion and incinerability is only an approximation. Presently, there is not sufficient research in this area to recommend an alternative method to the heat of combustion approach.

An example of this approach can be seen in Table 1. The constituents are listed in order of increasing incinerability. From these values, the tetrachloromethane and the chlorobenzene should be designated POHCs based upon the heat of combustion values and concentrations, respectively. The 1,1,1-trichloroethane might also be designated a POHC in the event that 99.99% DRE is not achieved for tetrachloromethane.

An important rule to remember is: do not choose a POHC which is a product of incomplete combustion (PIC). Currently, regulations do not control the emission of PICs. There have probably been many situations in which the PIC produced from a POHC was also a designated POHC for the same waste feed. As an example, laboratory studies reveal that the degradation of chloroform yields carbon tetrachloride and tetrachloroethylene. A list of selected POHCs and their PICs are presented in Table 2. The formation and measurement of PICs as POHCs add complexity to the interpretation of the DRE results. Based upon the formula for determination of DREs, $100(W_{in}-W_{out})/W_{in}$, the formation of PICs would cause abnormally low DRE results. W_{in} is the mass flow rate of the POHC into the incinerator, and W_{out} is the mass flow rate of the POHC in the stack gas emissions.

The permit writer should also consider limitations of stack gas sampling and analytical techniques when designating POHCs. Certain problems associated with various compounds include water solubility, contamination, poor recovery, and high reactivity. A list

Table 1. Greatest Concentration and Heat of Combustion

Hazardous Constituent	% Concentration	Heat of Combustion (kcal/gram)
Tetrachloromethane	1	0.24
1,1,1-Trichloroethane	6	1.99
Chlorobenzene	28	6.60
Phenol	9	7.78

Table 2. POHCs and PICs

Designated POHC	Products of Incomplete Combustion
Carbon Tetrachloride	Tetrachloroethylene Hexachloroethane
Chloroform	Tetrachloroethylene Carbon Tetrachloride
Chlorobenzene	Benzene
Toluene	Benzene
Trichlorobenzene	Chlorobenzene Dichlorobenzenes
Kepone	Hexachlorobenzene
Pentachloroethane	Tetrachloroethylene
PCBs	Chlorinated dibenzofurans

of selected problem POHCs is presented in Table 3. For example, dichloromethane is a solvent commonly used in laboratory environments. Care should be taken to ensure that contamination of the samples does not occur. Traces of formaldehyde, benzene, and chloroform are often found during the analysis of samples and blanks. Organic compounds with boiling points between 100 and 140°C offer a unique situation since these compounds can often be sampled with either the VOST or the Modified Method 5 (MM5). Laboratory evaluation of the sampling methods may be necessary to determine which method is appropriate.

In addition to choosing the designated POHC, the quantity of the POHC in the waste feed should be examined. The POHC concentrations should be high enough to ensure that the analytical detection limits are achieved. Also, an increase in the quantity, resulting in a higher sample catch, would reduce the effects of contamination.

Operating Conditions

The results of the trial burn are the principal basis for setting the conditions of the operating permit. Data and information obtained should give an accurate description of the incinerator's performance. The most important parameters which dictate the operating condition should, at a minimum, include POHCs of lowest heat content and greatest concentration, CO level in the stack gas, waste feed rate, total thermal input rate, combustion temperature, and combustion gas flow rate. The permit writer's evaluation of the trial burn conditions is to ensure that the data generated is likely to establish the incinerator's capability of achieving the performance standards.

From an operator's standpoint, the trial burn operating conditions should be designed to ensure the greatest flexibility in permitted operation. If compliance is shown at only one operating condition, the resulting permit will restrict operation only to those parameters, regardless of changes in waste composition or feed rate. To obtain the greatest flexibility, testing could be performed at the maximum thermal input and waste feed rate. Adversely, this approach would also cause operations to proceed under worst-case conditions, maximizing the chance of failure. Therefore, the applicant may consider operating at the most severe and lenient conditions, in addition to some intermediate conditions.

The trial burn could also be used as an opportunity to experiment with the incinerator to determine if operating costs can be reduced. The operating conditions could be designed with a lower combustion temperature, increasing feed rate, or reduced auxiliary fuel.

Appropriate Sampling Methods

Feed Samples

The sampling methods used for waste feed material depend upon the exact form of the waste (solid, sludge, liquid, etc.). Sampling for liquid wastes is usually performed according to the Coliwasa and tap methods. The Coliwasa, a composite liquid sampler, is designed to handle free-flowing liquids and slurries, including multiphase wastes. To collect a waste, the sampler is slowly lowered into the waste container and a liquid sample is removed and transferred to a storage container. The primary limitation is that the sample depth cannot exceed 1.5 meters. For depths up to 3.5 meters, the dipper (pond sampler) may be more appropriate. To obtain samples from large storage tanks, wells, or other containers which cannot be adequately sampled with the other devices, a weighted bottle may be used.

The tap sampling method is appropriate for liquid waste in pipes or ducts. A sampling line is attached to the tap and inserted into the sampling bottle. The tap is opened to allow flow such that the time required to fill the sample bottle exceeds five minutes. Prior to sampling, the sample line and bottle should be flushed several times with the sample material.

For solid waste samples, the grain sampler (thief), the sampler corer (trier), and the trowel (scoop) are most suitable. The grain sampler consists of two slotted

Table 3. Selected Problem POHCs

Compound	Cause of Problem	Possible Solution
Acetonitrile	water soluble	
Acetyl chloride	decomposition	
Aflatoxins	high toxicity	
Aniline	water soluble	
Benzene	contamination	
Benzenearsonic acid	low volatility	derivative with HI
Bis(chloromethyo)ether	decomposition	
2-Butanone peroxide	reactive	
2-sec-Butyl-4-6-dinitrophenyl	acidic-extracts poorly	
Chloral	water soluble	
Chloroform	contamination	
Coal tars	complex mixture	
Creosote	complex mixture	
Cyanogen	gas	
Cyanogen bromide	gas	
Cyanogen chloride	gas	
Cycasin	low volatility	
Dibutyl Phthalate	reactive	
Dichloromethane	contamination	
N,N-Diethylhydrazine	unstable	
1,1-Dimethylhydrazine	unstable	
1,2-Dimethylhydrazine	unstable	
1,4-Dioxane	water soluble	sample with MM5 train
1,2-Diphenylhydrazine	unstable	
Diphenylamine	basic-extracts poorly	
Formaldehyde	water soluble	derivative to sample
Formic acid	water soluble	
Hydrazine	unstable	
Hydroxydimethylarsine oxide	low volatility	derivative to sample
Iron dextran	high molecular weight	GPC
Maleic anhydride	unstable	
Maleic hydrazide	unstable	
Methyl ethyl ketone	poor recovery	
Mustard Gas	highly toxic	
Nitroglycerin	exposive	
Phenylmercury acetate	low volatility	derivative with HI
Phósgene	highly toxic	
Phthalic Anhydride	highly reactive	
Pyridine	water soluble	
Selenourea	low volatility	special HPLC column
Toluene	contamination	
Toluene diisocyanate	water soluble	
Vinyl Chloride	poor storage	

telescoping tubes, with the outer tube containing a conical pointed tip on one end which permits the sampler to penetrate the material. The sampler is opened and closed by rotating the inner tube.

The sampling corer is usually a long tube with a slot that almost extends the entire length of the tube. The sampler is inserted at an inclined angle and withdrawn with the open portion pointed upwards. This sampler is similar to the grain sampler but is preferred for moist or sticky materials. The trowel resembles a small shovel. These methods are also applicable for the sampling of ash. Scrubber water samples may be sampled by the dipper or tap method.

To achieve a representative sample, liquid samples should be collected every fifteen minutes and composited for each run. Duplicate samples should be taken in the event one of the samples is damaged or contaminated. Solid samples should be collected using the most practical method for representative samples of each type of solid waste used in the trial burn.

In certain circumstances, these waste feed sampling methods may not be appropriate. For example, a large storage tank containing a nonhomogeneous liquid waste mixture may cause sampling problems. The weighted bottle is considered appropriate for depths greater than 3.5 meters, but is not appropriate for multiphase wastes. The tap method could also be used, but, with a nonhomogeneous waste, the collected samples may produce distorted results. This may cause an excessively high or low POHC feed rate which would bias the DRE results. As an alternative, measurements of the material used to make up the waste feed may be used to determine POHC feed rates. Determining the POHC

concentration from the components of the waste feed material may be more appropriate than collecting composite samples by conventional methods which may not be representative.

Particulate and Hydrogen Chloride

Particulate and hydrogen chloride (HCl) emissions testing is performed according to EPA Reference Method 5. Sampling encompasses EPA Methods 1 through 5 as defined in the 40 CFR Part 60, Appendix A. Method 1 shall be used for the determination of the sampling points. Method 2 shall be used for velocity measurements. Method 3 shall be used for O_2 and CO_2 measurements. Method 4 shall be used for moisture determinations. Method 5 shall be used to determine the concentration of particulate matter in the incinerator effluent gas. The Method 5 train can be modified to capture chlorides as well. The modification will consist of replacing the water in the first two impingers with caustic solution.

Each particulate test run shall be performed in conjunction with the POHC sampling, and a minimum of 30 dry standard cubic feet of sample gas shall be collected during each run. The average sampling rate for each run shall be within ± 10% of 100% isokinetic conditions. Reference Method 5 analytical procedures shall be used for the determination of particulate emissions. Ion chromatography or EPA Method 325.3, mecuric nitrate titration, has been used for the determination of HCl emissions.

POHC Sampling

Stack gas sampling for the designated POHCs is the most important aspect of the hazardous waste incinerator permitting process. The two most widely used sampling methods, the Volatile Organic Sampling Train (VOST) and Modified Method 5 (MM5), will be discussed.

The VOST is applicable for capturing compounds with boiling points between 30 and 100°C. For compounds with boiling points below 30°C or between 100 and 150°C, lab verification of the sampling method is required. The sensitivity of this method is generally between 100 ng and 50 μg. In certain situations the lower and upper detection limits can approach values of 10 ng and 100 μg, respectively. An example of the VOST can be seen in Figure 1. This design employed by Entropy makes use of a few basic modifications to the original sampling protocol. The condensate trap has been replaced by a disparger tube and the second condenser has been removed. Some cases may require analysis of the aqueous condensate when sampling is performed for water soluble POHCs. The disparger tube is used to purge any POHCs which may have been trapped in the condensate. The second condenser has been removed from the train to prevent condensation from flowing into the tenax/charcoal. Condensation upon the backup sorbent trap would greatly reduce the capture efficiency of the charcoal half of the trap. As shown in the figure, the sampling train is surrounded by an Atmos glove bag. The purpose of this bag will be discussed in a later portion of this paper.

The protocol developed for the VOST recommends the use of 6 pairs of cartridges per run. The purpose for this approach is to ensure that the detectable range is achieved by combining samples. From our experience, the detectable range can be achieved with the use of only 3 pairs of traps. This approach also reduces the sampling time and analytical costs. Sampling is usually performed at a sampling rate of 1 liter per minute for 20 minutes with a sample volume for each pair of traps not to exceed 20 liters. For compounds with boiling points below 30°C and with expected high concentrations, SLOW-VOST, a smaller sampling volume or slower sampling rate, may be more desirable. For example, SLOW-VOST could be either a sample volume of 5 liters with a flow rate of 0.25 liters per minute for 20 minutes or a sample volume of 20 liters with a flow rate of 0.5 liters per minute for 40 minutes.

The analyses of the VOST sorbent traps are performed according to the purge-trap-desorption followed by GC/MS. Samples are thermally desorbed with organic-free nitrogen and passed through a water filled purge column onto an analytical trap. The trap is heated, and the effluent gas is directed into the GC/MS.

The Modified Method 5 (MM5) sampling train is designed to handle vapor phase organic compounds with boiling points greater than 100°C. This sampling train (See Figure 2) is adapted from the components typically used for EPA Method 5 sampling. The basic modifications include the addition of a sorbent module containing XAD-2 resin preceded by a condenser used to cool the gas stream below 20°C. The average sampling rate for each run shall be within ± 10% of 100% isokinetic conditions. The sampling period for the MM5 can range from 1 to 6 hours depending upon the analytical detection limit. An advantage of this sampling method is the ability to increase the sampling period to ensure the POHC sample catch is within the appropriate analytical detection range. However, a longer sample period increases the possibility of stripping the POHCs from the XAD-2 resin. For this reason, it may be more appropriate to increase the POHC concentration in the waste feed than to increase the sampling period. All surfaces that contact the sample, except the nozzles and probes greater than 7 feet in length, are constructed of glass or Teflon®. The major advantage of this system is that particulate loadings can also be determined. Sampling can also be modified to capture hydrogen chloride by replacing the distilled water in the impingers with caustic solution. To perform the analyses, the compounds are first extracted by solvent from the various components of the sample train, then analyzed by gas chromatography and mass spectrometry. The lower detection limit for this analytical approach is typically 10 ng.

Representative Samples

Using the appropriate sampling methods alone will not ensure quality, representative samples. To determine the desired sampling rate and period, the expected stack gas

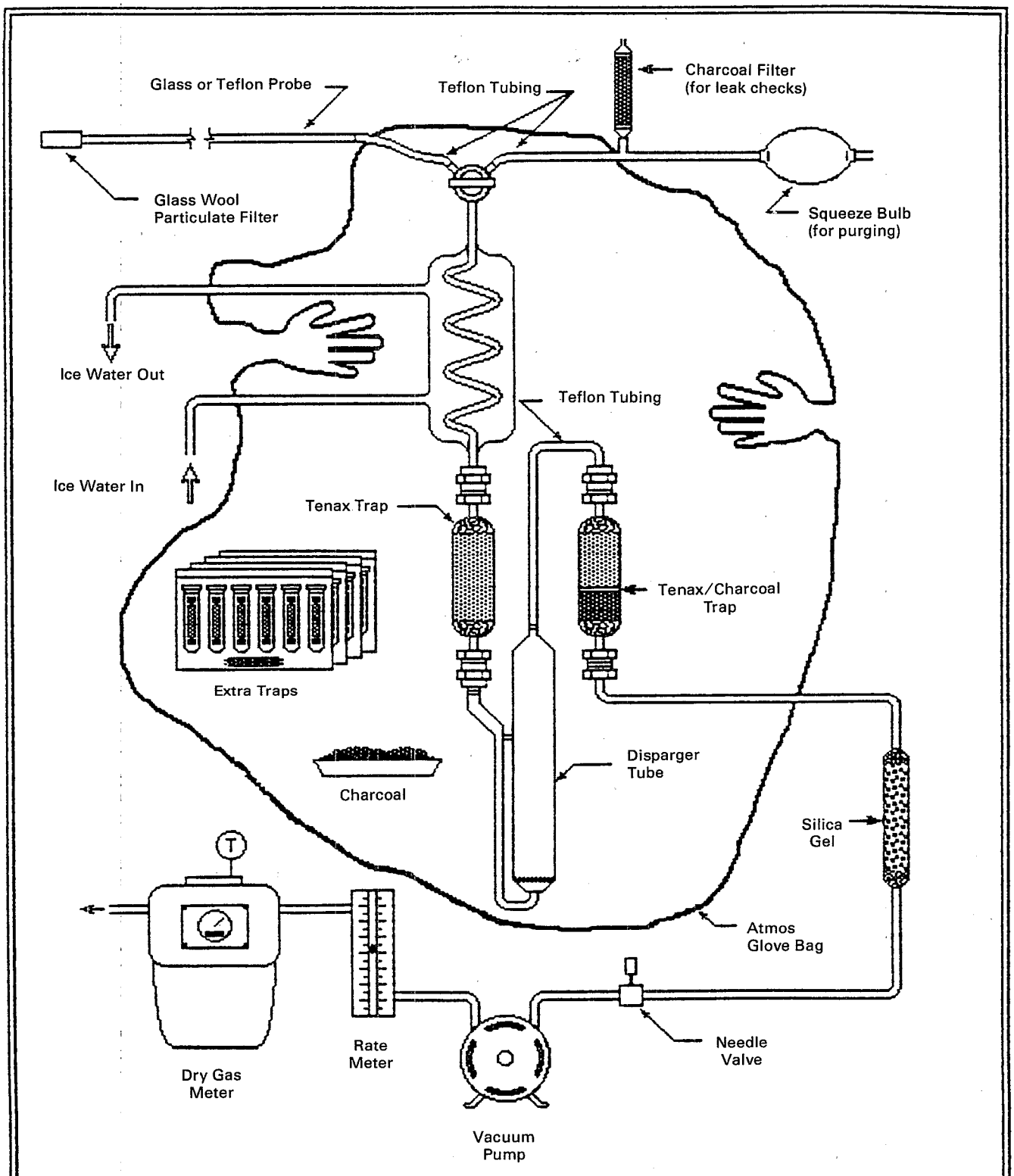

Figure 1. Volatile organic sampling train (VOST).

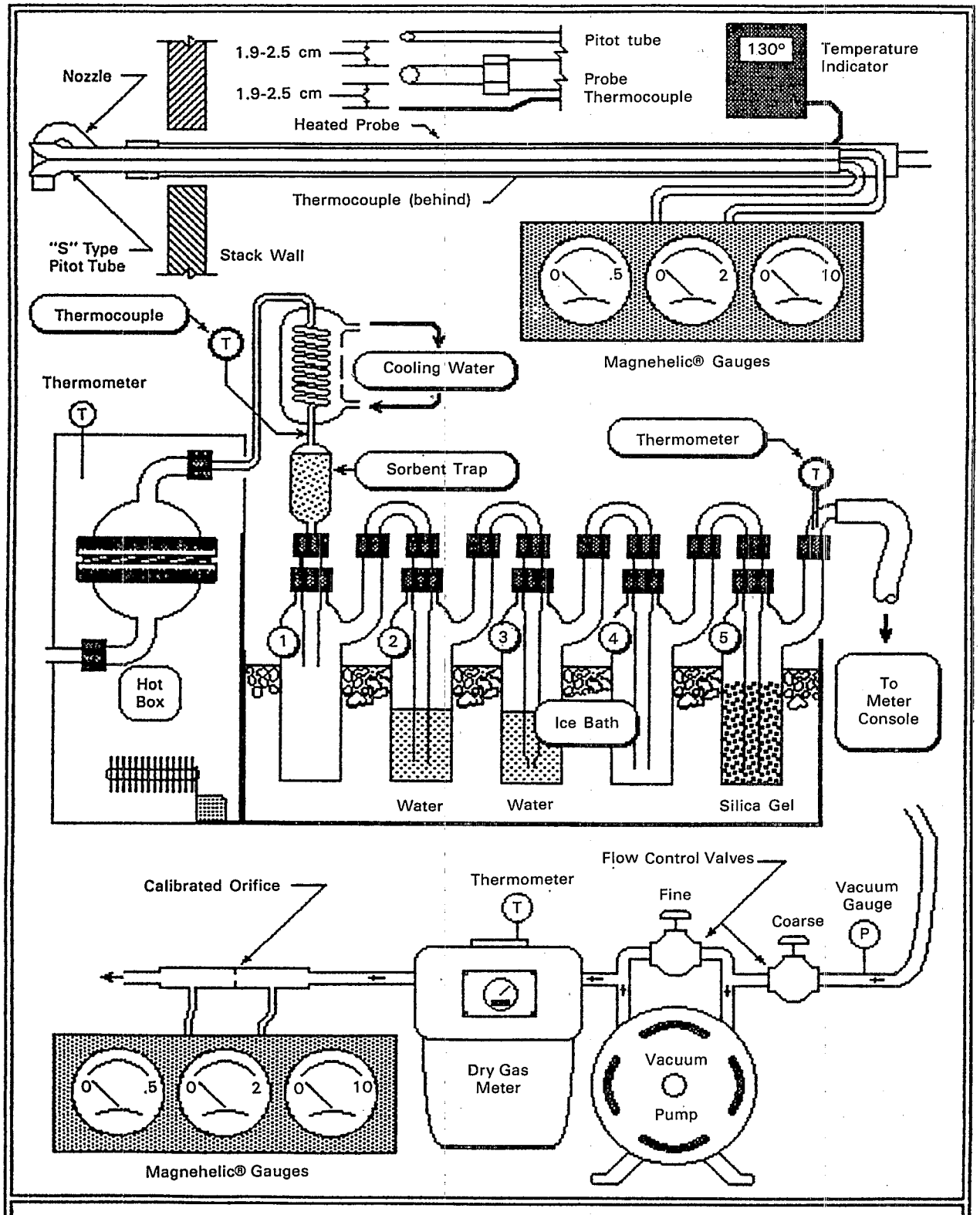

Figure 2. Modified Method 5 (MM5) sampling train.

concentration must be calculated. These calculations should be based upon the POHC feed rate, the stack gas volumetric flow rate, and the expected DRE results. The detection range for the various analytical methods dictates the sample catch required.

Following is an example of how to determine if the VOST sampling procedures will achieve the appropriate detection range. Using the information provided, the emission rate, POHC concentration in the stack gas, and POHC sample catch can be determined. The emission rate is based upon the inlet POHC feed rate and 99.99% destruction and removal efficiency (DRE). The stack gas concentration is the emission rate divided by the stack gas volumetric flow rate. The sample catch is based upon the normal VOST sample volume of 20 liters. As displayed in this example, the sample catch of 1.78 μg per sample is within the detection range of 100 ng to 50 μg. Also shown in the example are a decreased and increased POHC feed rate with sample catches outside the detection range. For the sample catch below the detection range, the POHC concentration in the waste feed must be increased or an alternative sampling method must be chosen. The sample volume must not exceed 20 liters and therefore cannot be increased to achieve the appropriate detection level. For the sample catch above the detection range, a smaller sample volume, obtained from the use of SLOW-VOST, would lower the sample catch to within the detection range.

Detectable Range:

POHC Feed Rate – 10 lb/hr
Stack Gas Volume Flow Rate – 3000 dscfm
Expected DRE Results – 99.99%
Detection Range – 100 ng to 50 μg

Emission Rate:

$$0.001 \frac{lb}{hr} * 453.593 \frac{g}{lb} * \frac{1\ hr}{60\ min} = 0.00756 \frac{g}{min}$$

Stack Gas Concentration:

$$0.00756 \frac{g}{min} * \frac{1\ min}{3000\ dscf} * 1{,}000{,}000 \frac{\mu g}{g} * \frac{1\ scf}{28.317\ liter} =$$

$$0.089 \frac{\mu g}{liter}$$

Sample Catch:

$$0.089 \frac{\mu g}{liter} * \frac{20\ liter}{sample} = 1.78 \frac{\mu g}{sample}$$

POHC Feed Rate	Sample Catch*
0.01 lb/hr	1.78 ng
500 lb/hr	89.0 μg

*Based upon 20 liters of sample volume for each VOST sample.

A major consideration is the prevention of contamination. If contamination has occurred, the resulting DREs could be much lower than desired. For this reason, the use of field, trip, and laboratory blanks should be incorporated into the trial burn. Field blanks are prepared at the sampling location. Field blanks should be treated in the same manner as a normal sample with the exception of bypassing the sampling procedures. The VOST field blanks should be exposed to the atmosphere for the required amount of time needed to switch a pair of tubes. The MM5 field blank should consist of a completely assembled sampling train. This train will be placed at the sampling location for the same amount of time which is necessary to conduct a run. The train will then be disassembled and cleaned according to the normal sample recovery procedures.

Trip blanks will be transported and stored on site in the same manner as the samples. Laboratory blanks will be stored in the laboratory to determine if contamination may have occurred during preparation or storage. If contamination has occurred, the use of the various blanks should help identify the source of contamination.

The environment around a hazardous waste incinerator is an undesirable location for Tenax, since POHCs are present in the ambient air. The objective of the VOST is to capture the designated POHCs from the stack gas without contamination from the ambient air. This is accomplished most efficiently by surrounding the sample collection part of the VOST with an atmospheric glove bag (See Figure 1). All of the tubes needed for the day's sampling are placed inside the bag. An open dish of charcoal, designed to capture any hydrocarbons which cause contamination, is also placed in the glove bag before sealing. At the end of the testing day, the glove bag is opened and the sealed cartridges are removed.

Conclusions

The first step to developing a successful trial burn plan is to identify the problem. This includes understanding regulations, incineration, and needs of individual facilities. Each facility will have different needs and will present different problems. It is the responsibility of the applicant and permit writer to satisfy those needs and anticipate those problems.

Cooperation has an important role in the development of a trial burn plan. The permit writer and applicant have different duties, but have a common goal (permitting the incinerator). The permit writer wishes to obtain sufficient data necessary to establish permit conditions, while the applicant wishes to obtain a permit which allows the greatest flexibility of incinerator operating parameters set forth in the final permit.

In order to understand the problem, competent, qualified personnel are a necessity. Both the applicant and permit writer should have an excellent knowledge of RCRA regulations and incineration. In some cases, a consultant experienced in these areas may be beneficial. The choice of sampling methods and obtaining quality,

representative samples should be the responsibility of a testing firm.

Organization is essential to ensure smooth and efficient development and implementation of the trial burn plan. A great deal of planning and research is necessary to obtain the most advantageous waste feed, POHCs, and operating conditions. Once the plan has been developed, implementing the test plan requires organizing the efforts of the permit writer, applicant, and testing firm towards a common goal.

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Trial Burn Plan Evaluation

By

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Introduction

Alternatives to land disposal of hazardous wastes are urgently needed. Land disposal leads to complete evaporation of volatile organic hazardous constituents of the waste, and to the contamination of ground water and of surface water.

Combustion of organic hazardous waste is an inherently good treatment method. However, public concern and regulations within the Resource, Conservation, and Recovery Act require that the permitting of hazardous waste incinerators is done in a technically competent and comprehensive manner. In order to permit a hazardous waste incinerator to operate, a demonstration of the performance of the system must be done. This demonstration is called a "Trial Burn." The proper evaluation of a Trial Burn Plan is one of the key issues to insure the success of a hazardous waste incineration project.

Evaluation of Completeness of the Trial Burn Plan

The first step in evaluating a Trial Burn Plan is to determine if the Plan is complete, with the appropriate level of detail. The appropriate level of detail is enough information to design, construct, operate, and maintain the facility and to conduct the entire Trial Burn and data reduction. The primary areas which must be included are the design of the combustor and air pollution control equipment, a full description of the waste, the detailed operating protocol, the sampling and analysis protocol, the continuous monitoring protocol, and a detailed test schedule and coordination plan.

The description of the design of the facility must be fully included. The combustion system description must at minimum include the design or construction drawings, the piping and instrument diagrams, and the control systems diagrams with the waste-feed interlock systems. The specifications and locations of the burners and air registers must also be included, as well as the complete mass balance, energy balance, and heat transfer calculations utilized to design the combustor.

The air pollution control equipment must also be fully described. The appropriate drawings must be included, and the full mass balance, absorption, and other appropriate calculations must be included.

Full characteristics of the waste must be indicated in the Trial Burn Plan. The molecular composition must be included, especially with an identification of any hazardous organic constituent listed in Title 40 of the Code of Federal Regulations (C.F.R.) Part 261, Appendix VIII. Also, an "ultimate" analysis (elemental composition) of the waste should be included in order to perform the mass balance calculations for the flue gas composition and stoichiometric air requirements. The Principal Organic Hazardous Constituents (POHCs) should be recommended for each waste stream. The POHCs will be the constituents for which performance tests, including Destruction and Removal Efficiencies (DRE's), will be done during the Trial Burn. The POHCs shall be chosen on the basis of highest concentration found in the normal operating waste stream, and on the basis of highest degree of incinerability. Additionally, the waste feed rate for each test series should also be specified, as well as the waste feed rate to each burner.

One area that is often not given full attention is the detailed operating protocol. All operating parameters and operating levels must be specified for the entire combustion system. Some of the primary areas which must be addressed for the combustor are the waste mass flow rate and composition, combustion temperature fields, combustion gas velocity fields (for both residence time and turbulent mixing considerations), waste burner atomization pressures, and the key indicators of stoichiometry and performance: the concentrations of carbon monoxide, oxygen, and total unburned hydrocarbons in the combustor exit gas stream. A few of the key parameters which must be addressed for the air pollution control equipment are the liquid-to-gas mass flow ratios, liquid pH, pressure drop and voltage potential (for electrostatic precipitators).

The sampling and analysis of the waste, combustion exit gas stream, scrubber and other liquid discharge streams, and of the ash must be addressed. A detailed protocol must be developed which includes the schedule, equipment requirements and backup systems, and personnel (including contractors). Quality assurance and quality control programs should be defined in detail. The exact methods and protocol must be specified in all aspects of the sampling and analysis of each species, with the limits of detection listed for each species.

Continuous monitoring of the operating parameters and indicators of stoichiometry and performance must be defined. The methods and equipment must be specified, and must meet the performance specifications in 40 C.F.R. 60, Appendix B. The instrument and control diagrams for the waste feed interlock/cutoff systems must be included, as well as a description of these systems. The waste feed cut-off levels for each of the operating and performance parameters must also be specified.

Finally, the detailed test schedule and coordination plan must also be enumerated in the Trial Burn Plan. The proposed dates of the tests and the duration of each test due to sampling requirements and time to reach steady state operation must be specified. The test schedule and protocol must specify and summarize all of the parameters that are discussed in this section.

Once all of this information is specified in complete detail, the Trial Burn Plan must be evaluated for adequacy.

Evaluation of Adequacy of Trial Burn Plan

The evaluation of the adequacy of the Trial Burn Plan is the evaluation of the adequacy of each item decribed in the section above (Section II). The primary concerns are if the technical approach and methods are sound and if the data will be sound, whether or not the anticipated data can be translated into permit conditions, and if areas of public concern are addressed.

For example, in evaluating the design of the combustion system the calculations indicate that for one of the waste streams at the maximum waste flow, the maximum air delivered will only produce a combustion exit gas oxygen concentration of 1%. This will probably not be enough air to achieve the performance requirements, so that this portion of the Trial Burn Plan (the design of the combustion system) is not adequate.

The information in the Trial Burn Plan should also be adequate to anticipate the type and form of permit conditions which would be developed from the Trial Burn. In essence, this means that a draft of the Permit should be written from the Trial Burn Plan, with the actual Trial Burn data utilized in confirming the conditions of the Permit. For example, in one case the Trial Burn Plan requires for a particular test series several combustion temperatures (one temperature per test) and all other parameters are required to be held constant. If the performance standards are achieved for all of these tests, the permit conditions for that particular waste stream and waste feed rate would be the minimum temperature achieved and a corresponding limit of the other parameters which were held constant.

Perhaps the most difficult question to answer is whether or not the data developed from the Trial Burn will be sufficient to satisfy the public. The public is asking increasingly more difficult questions and wants to know more details than ever before. The primary areas of public interest are in the areas of health effects from emissions, levels of emissions, complete molecular composition of emissions (the identification of all products of incomplete combustion), and the chances of explosion, releases, or other catastrophic events. The Trial Burn Plan should be designed to answer these questions based on, in part, the data from the Trial Burn.

Data in Lieu of Trial Burn (270.19(c))

Although the submission of data instead of performing a Trial Burn is not ideal, it has been done and is listed as an alternative in the regulations. Detailed information similar to that required for a Trial Burn Plan is required, and a similarity analysis must be performed on the combustion and air pollution control systems and on the wastes from both the proposed system and on the system on which the data were taken.

The information requirements include detailed waste analyses, a detailed design decription of both systems as indicated in Section II, a detailed waste comparison, a detailed comparison of operating conditions, a detailed comparison of the combustor and air pollution equipment design, and the test results in the appropriate form.

An analysis of the similarity of combustion systems is extremely complex. In order to fully understand a combustion system, a thorough knowledge of each fundamental and practical aspect of that system should be acquired. The systems should be examined in terms of the local fluid dynamics, combustion chemical kinetics, heat transfer, mass transfer, and thermodynamics. Additionally, the practical aspects such as monitoring devices, fans, burners and burner orientation, and fire brick should be examined. The data for such an analysis is usually not readily available for full scale units.

The similarity analyses should be performed with the data available. The aspects of similarity examined for the combustor should be geometric, dynamic, chemical, and thermal similarities. For geometric similarity, the ratio of all length scales and angles should be proportional. Dynamic similarity exists when all forces on the gas streams are proportional. This analysis may be facilitated by requiring a similarity of Reynold's Numbers. Chemical similarity exists when chemical concentrations within the combustion chambers are proportional. Thermal similarity requires that temperature fields are proportional.

The similarity of the air pollution control equipment must also be examined. While every type of device has some effect on organic, HCl, and particulate emissions, these devices can be classified into two categories. Gas-liquid contacting devices primarily remove HCl from the gas stream. Gas-solid contacting devices primarily remove particulates from the gas stream.

The primary parameters to evaluate similarity for the gas-liquid contacting devices are the liquid-to-gas mass ratio, pressure drop, gas residence time, liquid pH, temperature, and the contacting area. For the gas-solid

contacting devices the main parameters to examine for similarity are gas residence time, contacting area, temperature, and voltage potential (if applicable).

Translating Trial Burn Results into Permit Conditions

The ultimate test to determine if the Trial Burn Plan is adequate is if the anticipated data can be translated into permit conditions. Test protocols should be developed which include all operating parameters. The protocols should be developed such that the primary operating parameters are de-coupled, ideally done by the variation of only one parameter with all other parameters held constant.

The primary variables which should be examined during a Trial Burn are derived from a simplified combustion theory. The effect of residence time, temperature, turbulence, and stoichiometry on performance should be examined.

As in any experiment, it is essential to control the primary parameters during a Trial Burn. This is sometimes difficult to achieve in many full scale combustors, primarily because the instrumentation and controls do not have a high enough resolution. However, it is important to aim for tight control of the variables when performing the Trial Burn, and also during hazardous waste operation.

When examining the effect of one fundamental parameter on performance during a Trial Burn, it is essential to hold all other parameters constant. If this is not done, it is impossible to de-couple the relative influence each fundamental parameter has on performance. This is extremely important when setting permit conditions.

Although this approach appears to be very expensive and time consuming, it is an ideal which can be utilized in order to prioritize the data taken during the Trial Burn. Again, the main conditions of the Draft Permit should be based on the Trial Burn Plan, with confirmation of these conditions by actual Trial Burn data.

Summary

When permitting a hazardous waste incineration system for construction and operation, the Trial Burn Plan must be carefully evaluated. The Trial Burn Plan must be complete, it must be technically adequate and must address public concern, and the Draft Permit should be written based upon the details of the Plan. Additionally, utilizing data instead of performing a Trial Burn is an option which also must be carefully examined. The comprehensive evaluation of the Trial Burn Plan is a necessary step in insuring a technically sound incineration system and in overcoming the hurdle of public concern which will ultimately determine if the project proceeds.

Conducting the Trial Burn

By

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Introduction

The trial burn is conducted in order to evaluate an incinerator's performance with respect to RCRA Part B requirements. Although the requirements which must be met are the same for all incinerators, each trial burn is unique because of the incinerator design, incinerator operation, waste feed type, and Principal Organic Hazardous Constituents (POHCs) chosen. The details of how the trial burn is to be conducted (e.g., POHCs chosen, incinerator operating conditions, sampling and analysis methods) are addressed in the trial burn plan. The intent of this paper is to present, in a general sense, guidance on conducting the trial burn. The purpose is to provide an overview with respect to implementing a trial burn for those unfamiliar with what is involved. Details and principles related to preparing a trial burn plan (i.e., POHCs to choose) are not addressed. The paper discusses:

- Key personnel involved in implementing a trial burn
- Key activities which must be coordinated
- Typical problems
- The trial burn schedule, and
- Improved execution of a trial burn

Planning the Trial Burn - Key Personnel

Prior to conducting the trial burn considerable time will have (or at least *should* have) been invested in preparing a detailed and comprehensive trial burn plan. If a well thought out trial burn plan has been prepared then conducting the trial burn is a matter of implementing the plan. Major questions and problems should have been addressed prior to initiating the trial burn. Hence, the process of conducting a trial burn is one of planning, managing, and coordinating in order to implement the plan. On paper, this sounds easy...in reality the process is more complex.

Planning, coordinating, and conducting a trial burn potentially involves a great number of different people--or a "test team." Table 1 identifies the key persons typically involved in conducting a trial burn. Persons from the facility, emissions testing firm, and agency(s) are involved. I use the term team, because in order to get the job done persons in all three sectors (facility, consultant, agency) must communicate and work together.

Table 1. Test Team

Trial Burn Coordinator	Project Leader	Permit Writer
Operations Manager	Field Crew Chief	Technical Leader for Sampling
Lead Operator	Analytical Task Leader	Technical Leader for Analysis
	Quality Assurance Officer	Quality Assurance Officer

Depending upon the complexity of the test and organizational structures of the company and agency, multiple people from each sector usually are involved. For example, the company's trial burn coordinator may be from a corporate environmental group not from the facility. Obviously, the facility manager also must be involved, as well as the actual incinerator operator. Because of the varied expertise required, i.e., sampling, analysis, regulatory--the agency also may have several people involved. Obviously, close communication and a clear understanding of objectives by all persons involved are necessary in order to coordinate and carry out the test. Hence, it is important that *all* parties be involved in the process as soon as possible, i.e. during planning and preparation of the trial burn plan.

The need for early involvement cannot be stressed enough. It is foolish for corporate engineering to write a trial burn plan and think about initiating the trial burn without involving the lead operator of the incinerator; after all the operator is most likely to know what the unit can and can't do. Likewise, problems and the need for revisions to the trial burn plan usually result if the consulting firm that will actually conduct the sampling analysis and reporting is not involved very early in the process of preparing the trial burn plan. Furthermore, the more collective experience with conducting trial burns available to the "team," the better. In other words, if personnel experienced with conducting trial burns can be found within the corporate structure, within a consulting firm, and within the agency, you should use it!

Key Activities

Table 2 presents a partial list of the key activities to coordinate during the trial burn. Note that the trial burn activities are divided into 3 general categories: (a) pretest activities, (b) activities required during the actual test and (c) post test activities. When one thinks of a trial burn there is a tendency to immediately focus on "stack emissions sampling." True the measurement of the stack emissions are a key part of conducting the trial burn; nonetheless, as examination of Table 2 indicates, it is only one of many parts.

First, in order to avoid unnecessary delays, the trial burn coordinator, facility manager, and test consultant must assure that any required site modifications are made *well in advance* of the date the trial burn is to begin (several weeks or months is much preferable to several hours). Because the trial burn is designed to test performance of the incinerator under *specific operating* and *waste feed conditions* as specified in the trial burn plan, the facility must assure that *sufficient* waste feed with the desired characteristics is available for the test. Also, since the trial burn data will be used to establish incinerator operating limits and monitoring requirements, it is necessary to assure that the process operation monitors (e.g. carbon monoxide monitor, waste feed rate monitor) are properly calibrated prior to initiating testing. Again, since alot of critical activities will be occurring just prior to and during the actual burn, these items need to be addressed well in advance of the burn.

During the actual conduct of the trial burn, the primary activities which must be closely coordinated include: (a) process operation and monitoring, (b) emission testing, and (c) collection of process samples (e.g. waste feed, scrubber water samples). All three functions are conducted simultaneously. All are equally important. Remember that how the incinerator is operated during the testing will ultimately affect the permit limits. For example, the operating permit generally will require that the incinerator combustion chamber temperature be maintained at a level greater than or equal to the minimum temperature demonstrated during the trial burn. Hence, it is very important that the facility *closely monitor* incinerator operation and coordinate with the test crew so that testing will not be started and is discontinued if the desired operating parameters are not being achieved. Proper understanding of the objectives to be achieved and good communication among all parties involved is essential. Similarly, because calculation of POHC Destruction and Removal Efficiency (DRE) includes both the input (waste feed) and output (stack gas emissions) of the chosen POHCs[a], the sampling/analysis of process samples is equally as important as the sampling/analysis of stack gas emissions. Therefore, process samples are taken simultaneously with the stack gas emission testing, usually at 15-30 min intervals. Depending upon the number of waste feed streams to the incinerator several people may be required simply to take process samples. Several different sampling trains will be required to collect stack gas emissions samples including, as a minimum, (a) a particulate/HCl sampling train, (b) an integrated gas sample (oxygen and carbon dioxide) and (c) volatile and/or semivolatile POHC sampling trains. It is obvious that the number of activities and persons to supervise and coordinate for a single test is significant.

Table 2. Activities to Coordinate

Pretest:
• Site Modifications
• Waste Feed Preparation/Availability
• Process Monitor Calibration
During Test:
• Process Operation/Monitoring
• Pollution Control System Operation/Monitoring
• Emissions Testing
• Process Samples Testing
• Data Records
• Safety
Post Test:
• Sample Transport/Transfer
• Analysis Directive
• Analysis
• Reporting

The trial burn does not end when the sampling is completed. The transfer of samples to the analytical laboratory and the subsequent sample analysis and reporting of results constituents a substantial part of the overall trial burn effort. The number of analyses to be conducted are numerous and the analytical parameters and protocols vary depending on the type sample. Hence, it is essential that a written analyses directive be prepared and submitted with the samples. In reality, this must be planned well in advance of the testing. Many organic samples, especially when analyzing for volatiles, have specific "holding time" requirements. Consequently, test samples often are shipped from the field directly to the laboratory on a daily basis. This requires that the laboratory knows what samples to expect, when to expect them, and specifically what analyses are to be conducted. For a complex trial burn involving sampling of 3 different waste input streams; scrubber water influent and effluent; incinerator ash; and volatile, semivolatile and particulate stack gas emissions, a three run trial burn can easily generate 50 individual samples. Most samples will be analyzed using different methods for multiple analytes (e.g., semivolatiles, ash, high heat value). In short, proper planning and coordination is required between the field and laboratory personnel.

Finally, the field, laboratory, and facility personnel must coordinate tabulation, interpretation, and reporting of all results before one can truly say the trial burn is completed.

[a] $\text{DRE} = \frac{\text{POHC Input Rate} - \text{POHC Output Rate}}{\text{POHC Input Rate}} \times 100$

Special Concerns and Common Problems

Some of the more common problems and special concerns associated with the trial burn are:

1. The incinerator cannot achieve all desired conditions simultaneously.
2. The incinerator has never been operated at the test conditions for any length of time.
3. Special preparation of waste feed may be necessary.
4. Process upsets and deviations from protocol.

As previously mentioned, since operating permit limits will be based on the operating parameters demonstrated during the trial burn, the chosen trial burn operating conditions are extremely important. Generally, "worst case" operating conditions are desired, that is:

- Operating conditions
  - —Maximum heat input rate
  - —Minimum combustion temperature
  - —Maximum waste feed rate
  - —Minimum O_2 concentration in stack gas
  - —Maximum air input rate (maximum gas flowrate to yield minimum residence time)
  - —Maximum CO content in stack gas
- Waste characteristics
  - —Maximum concentration of selected POHCs
  - —Maximum Cl content
  - —Maximum ash content
  - —Minimum heating value (HHV) of waste feed

It is not always possible to simultaneously achieve all the worst case conditions. For example, maximum air input rate (lowest residence time) and minimum O_2 concentration may be mutually exclusive. Furthermore, and perhaps of more concern, is the fact that a facility in attempting to achieve "worst case" conditions may be operating at test conditions never before attempted. Not only may the conditions not be achievable, but potential problems with operation may appear during the trial burn. For example, if the ash content of the waste is significantly increased from the normal level, plugging of waste feed nozzles during the trial burn may occur. Similarly, the waste feed system may be prone to failure if it is operated at or beyond its maximum design level. Obviously, the wise approach is to determine the desired operating conditions well in advance of the trial burn and then proceed through a well designed step by step "shakedown" to assure the desired operating conditions can be achieved and to identify potential equipment and operating problems. During this "shakedown" it may be desirable to test the performance of the incinerator with respect to selected RCRA performance criteria. For example, if the waste feed rate and ash content of the feed are significantly increased, it is wise to conduct a particulate emissions test to assure that the pollution control system is adequately performing. This approach of selectively evaluating performance is often referred to as conducting a "miniburn." Miniburns typically are conducted to evaluate particulate or HCl performance or to evaluate DRE under varied operating conditions such as a lower combustion chamber temperature, increased feed rate, or different waste type. The concept of a "miniburn" applies to new and existing facilities. Of course, in all cases one must assure that during a miniburn applicable permit limitations (if any) are not exceeded. In the long run, this approach can be less time consuming and less expensive than going through a complete trial burn, failing to meet the particulate performance standard, and being required to repeat the trial burn.

As previously mentioned, since worst case conditions are desired during the trial burn, it generally is necessary to prepare a special waste feed or modify the normal waste feed so that the desired waste feed characteristics are obtained. This can become a logistics problem in terms of blending and storage of the large quantities needed for the trial burn. Waste feed homogeniety often is a problem. Proper planning is required. If there is any doubt about the success of preparing the desired feed, it should be attempted and checked out (i.e., sampled and analyzed) well in advance of the trial burn.

During the actual trial burn, deviations from the operating, sampling, and analysis protocols established in the trial burn plan will occur. No matter how well the trial burn is planned, some deviations generally are necessary. With regards to handling deviations, a distinction must be made between major and minor deviations. A minor deviation would include a minor change to the test protocol. For example, an extra impinger might be added to the semivolatile sampling train because of excessive moisture collection. Minor changes, should be documented in the test report. A major deviation is one that will affect permit limitations or the validity of the test. For example, if the combustion chamber temperature stipulated in the trial burn plan is 1700°F, the decision to operate at 1500°F is a major deviation. Agency personnel must be consulted prior to such a deviation because of the potential adverse impact on emissions during the trial burn. Similarly, if a decision is made to operate at 1900°F, the agency should be informed and the operator must realize that making such a change will impact on the operating permit conditions. That is, combustion chamber temperature limits of greater than 1900°F instead of greater than 1700°F would be established in the operating permit. The persons responsible (facility and agency) for making decisions regarding deviations should be identified before the trial burn.

Process upsets may occur during the trial burn emissions testing. The facility operator should be prepared with regards to handling such situations. Often a quick decision with respect to stopping an emissions test run or continuing the run will be required. The decision must be coordinated with the test consulting firm. It is useful to establish some general guideline before the trial burn.

The Trial Burn Schedule

Table 3 is an example schedule for conducting a trial burn. Each trial burn is unique and the schedule will vary

Table 3. Schedule

•	Incinerator Shakedown/Site Modifications
•	"Miniburns"
•	Monitor(s) Calibration/Evaluation
•	Preparation of Special Wastes
•	Pretest Meeting(s)
Day 1	Arrive On-Site
	Set-Up
	Sample Solid Wastes
Day 2	Complete Set-up
	Sample Solid Wastes
	Preliminary Measurements
Day 3	Run 1
Day 4	Run 2, Audits
Day 5	Run 3
Day 6	Pack Equipment/Leave Site
Day 4-8	Samples Arrive at Laboratory
Day 35-50	Sample Analysis Complete
Day 35-60	Preliminary Results Reported
Day 95	Test Report Submitted

according to the number of test runs, as well as, the sampling/analysis protocol. However, review of a "typical" schedule is beneficial with regards to reviewing a few key points. First, note that several items (e.g., site modifications) are presented in the schedule as being completed prior to initiating the trial burn. A "pretest meeting" is identified in the schedule. It is always useful for the facility, test consultant, and agency personnel to have a meeting just prior (within a month) to the test to review the final test protocol and discuss any last minute changes.

Note that the schedule indicates only one test run per day. The number of test runs conducted per day will depend upon the length of each test run and the complexity of the test protocol. One or two runs per day is typical. Actual sampling time for a test run usually is 2 to 4 hr. However, additional time is required to set-up the sampling equipment, conduct leak checks, change test ports during a run, and recover the sample. Furthermore, time is required to establish the desired incinerator operating conditions. Quite a few other additional activities also are generally required during the testing. For example, note that the schedule indicates conducting a field quality assurance audit (e.g. sampling of a volatile organic cylinder gas) during day 4. Hence, it is generally impractical to consider conducting more than one test per day; a 2- to 4-hr test can take from 5- to 10- hr.

The time required to conduct the sample analyses and data interpretation also is a function of the complexity of the test. Another important factor is how well the activities have been coordinated. If the laboratory is aware that the samples will be arriving, and the samples arrive on schedule, then analyses will proceed more smoothly. Delays in the field may have an adverse impact with regards to timely sample analysis. In general, because of the numerous activities and persons involved, any delay tends to have a domino affect on schedule. For this reason it is best to give careful consideration to the trial burn schedule during the planning stage. Establish a realistic schedule. Usually there is a great deal of pressure to achieve a tight schedule. If a very tight schedule is necessary, assure that the resources necessary (plus some) are available. Establishing unrealistic schedules will only cause delays, confusion and added costs.

The schedule shows the trial burn report submittal on day 95. This is 90 days after testing is completed; the RCRA regulations require report submittal within 90 days of completion of the test unless otherwise approved by the administrator.

Improved Execution of a Trial Burn

In summary, although each trial burn is unique, there are many key items common to conducting all trial burns. Early *identification* and *involvement* of *all* key personnel in planning and coordinating the trial burn will facilitate conducting the trial burn. A well designed trial burn plan of adequate detail will go a long way towards improving the execution of the trial burn. Careful attention to preparing a *realistic schedule* and identifying critical path items is necessary. Adequate time for "shakedown" of the incinerator and conduct of "miniburns" to evaluate the affect of untried worst case conditions should be included in the trial burn schedule, when appropriate. Trial burns are time consuming and expensive...a typical trial burn can cost from $50,000 to $150,000; it pays to do it right the first time.

Agency Observation of the Trial Burn

By

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Prior to receiving a permit to operate, the owner/operator of a hazardous waste incinerator must prove that emissions will be maintained at or below certain levels, as set forth in applicable standards. This must be accomplished during a trial burn, in which emissions are sampled and measured to determine a range of allowable waste feed compositions and rates amd incinerator operating conditions.

Observation of the trial burn is the appropriate control agency's best opportunity to both assess the conditions considered to be optimal process and control equipment operating conditions and to compare emissions to the applicable standards during these operating conditions. The trial burn observation involves three main objectives. The first objective is to certify that the testing methodology is proper and in accordance with the approved trial burn plan. The second is to develop an engineering profile of process and control equipment operating conditions which demonstrates that the test was conducted under representative conditions. The third is to establish a set of representative conditions (i.e., waste feed rate and composition, carbon monoxide levels, etc.) under which the incinerator emissions are within the required limitations. This set of conditions can then be used during subsequent inspections as an indication of changes in facility operations, control device performance, or other parameters that could result in an increase in emissions.

Incinerator and control equipment operation during the trial burn is of critical interest to the agency for several reasons. During the trial burn, the observer can usually determine the range of process and control equipment parameters that the facility operator and equipment supplier consider optimal for achieving compliance with applicable emission standards. This information is useful not only for establishing representative operating conditions during the trial burn, but also for selecting or evaluating stipulations of operating permits and for assisting agency inspection personnel in evaluating future performance of the incinerator. The overall process of establishing this benchmark set of operating data is called "baselining."

Establishing a baseline involves documenting all pertinent operating parameters as they relate to the emission characteristics of the source. This includes both process and control equipment parameters. The baseline provides a fixed point of operation or a narrow range of operating parameters against which other determinations may be made. Concurrent emission tests provide documented emission rates that may be correlated with process and control equipment operating characteristics.

The purpose of the trial burn observation is to evaluate the representativeness of the process operations, control equipment operations, sampling techniques, sample analysis, and reported results with respect to applicable requirements. If any one of the above mentioned items is determined not to be representative, the trial burn results are invalid.

Planning and Preparation

The initial phase of any trial burn observation is planning and preparation. During this phase the representative agency reviews the trial burn plan to determine if all procedures are acceptable. Typically, the carbon monoxide continuous emission monitoring system (CEMS) performance evaluation is conducted simultaneously with the trial burn. Observation of the performance specification test (PST) is beyond the scope of this paper; References 2 and 3 deal with PST observation.

The trial burn plan is submitted to the agency by the test consultant or the plant representative and reviewed to confirm that it meets all agency requirements. In particular, the agency/observer gives close attention to any deviations from standard sampling procedures, available sampling locations, and/or pollutants and proposed operation of the incinerator during the trial burn. With the trial burn plan agreed upon, the observer/inspector prepares for the actual test observation by further familiarizing himself with the incinerator operations and gathering any checklists, data sheets, etc., that he will need on the day of the test.

Prior to the trial burn the observer must be familiar with the incinerator and control equipment operations. He may conduct a walkthrough inspection to become familiar with the facility layout. The agency observer, the test team leader, and a plant representative with process

control authority should meet to confirm operating conditions and to coordinate the testing schedule. A pretest checklist can be used to organize the meeting and to ensure that all pertinent areas are discussed.

It is the observer's responsibility to be certain that all details of the test procedures are understood before the test begins. At the conclusion of the pretest meeting, the test team supervisor must know the exact sampling procedures to be used, the minimum data requirements, and the conditions that constitute an invalid test. Likewise, the plant representative should know what process and control equipment parameters must be recorded. the intervals of data collection, the waste feed rate that must be achieved, and the conditions that constitute an invalid test. Execution of the trial burn in accordance with the agreed upon trial burn plan should constitute a valid test.

The observer must become familiar with the process to be sampled. His understanding may be aided by consulting an agency process control engineer or by referencing one or more of the many inspection manuals prepared by the U.S. Environmental Protection Agency. These manuals generally describe the process, indicate the methods and devices used in monitoring incinerator data and address methods of emission control and control equipment performance evaluation.

The observer should also be prepared to handle any nonroutine situations that arise during the trial burn. Before the test begins, he should prepare a written or mental list of potential problems and possible solutions. The list should establish limits at which the minimum requirements for sampling are not met; for example, sampling may be unacceptable if the sampling train condenser cannot maintain the sample gas at or below the maximum temperature of 20°C. If the observer plans to use checklists, method modifications and anticipated problems should be noted on these. In preparing to meet such emergencies in testing, the observer must know who in his organization is authorized to make decisions that are beyond his capability or authority.

The number of persons scheduled to observe a trial burn should be adequate to allow the observation of process and control equipment operations, the recording of those observations, and the overseeing of sampling procedures. The observers' records should allow present and future evaluations of the representativeness of the test data and the validity of the testing methodology followed by the test team.

Trial Burn Observations

The attitude and behavior of the agency observer during the trial burn are of utmost importance. He should perform his duties quietly and thoroughly, conversing with the test team and plant personnel as little as possible. If test procedures do not follow the established trial burn plan, the observer should deal solely with the test supervisor and plant representative. Conversely, he should refrain from answering questions from the test team and incinerator operators directly, referring such inquiries to the appropriate supervisor. The ideal trial burn is one in which the data gathered is representative and no discussion of the test procedure is required.

During the trial burn, the observer or observers must perform a number of tasks to ensure that the test is representative and to construct a baseline set of data. These tasks include observation of sampling procedures, on-site estimation of possible measurement errors, observation of operational parameters, and confirmation of normal operations during the test.

The observer must make a number of checks to confirm the test team's adherence to specified sampling procedures and appropriate quality assurance measures. These checks are to ensure that the locations of the sample ports and sample points will provide samples representative of the atmospheric emissions and that the samples collected in the sample train are representative of the sample points.

In most cases the observer should utilize a checklist or checklists covering the details of the sampling procedures to eliminate the possibility of overlooking any necessary checks. Example checklists for each of the EPA reference methods can be found in Reference 1. These checklists contain all the necessary checks for the standard sampling methods. If the test team is using modified procedures of any type, the observer should modify or rewrite his checklists to reflect all modifications.

The observer must note and gauge the relative importance of potential measurement errors associated with the sampling and analytical techniques employed during the trial burn. Measurement errors can be classified as three types: bias, blunder, and random errors.

Bias errors, a deviation of the measured value from the true value in one direction, are generally caused by the personnel and equipment used during the sampling. Bias errors are normally dismissed upon receipt of adequate equipment calibration documentation, but, the observer may require a one-point calibration check prior to testing.

Blunder errors occur during sampling procedures and should be the main concern of the observer. For example, if the sample nozzle is allowed to touch the inner stack wall and collects foreign material from the wall, the resulting error may be extremely large. Such errors are difficult to observe and the total effect cannot be calculated. Fortunately, most of these errors can be dismissed using common sense rationalization.

Random errors, which result from a variety of factors, cause a measured value to be either higher or lower than the true value. Such errors are caused by inability of sampling personnel to read scales precisely, poor performance of equipment indicators, and lack of sensitivity in measurement devices. The usual assumption is that random errors are normally distributed about a mean or true value and can be

represented statistically in terms of probabilities. Determining the maximum expected error, however, does not require a strict statistical approach. It can be estimated by summing the maximum expected errors for each factor as explained in Reference 4.

During the trial burn, the agency observer must conduct an inspection to obtain the operating parameters necessary for evaluating the test and constructing the baseline. The only major difference between this and a routine inspection is the fact that emission testing is occurring simultaneously. Throughout the test, incinerator and control equipment parameters and other pertinent indicators should be checked.

As the initial part of this inspection, the observer should tour the facility ensuring that all monitoring equipment and sampling locations are acceptable, functional, and when necessary, calibrated. In particular, he should check the following items.

- Sampling port locations.
- Incinerator and control equipment sampling locations (waste feed, scrubber water discharge, etc.).
- Incinerator operations monitors and their calibration factors.
- Control equipment instrumentation and calibration factors.
- Continuous emissions monitors and their data recording equipment.

If any of these items are not acceptable by test time, the facility contact should be informed that the problem must be corrected prior to the test.

The primary process parameters monitored as part of the test include waste feed rate, combustion temperature, total volumetric air flow rate, and emission levels of carbon monoxide. Waste feed characteristics that should be monitored include the chemical composition, the size distribution of the feed materials (if applicable), and any feed cycles that are present if the feed is not continuous. To the extent possible, continuous strip chart recorders are valuable in providing real-time data and should be used where available. Otherwise, visits to process monitoring areas at a reasonable frequency are necessary to provide adequate documentation.

The actual monitoring and recording of the facility operations is the responsibility of the facility. The observer's responsibilities are to see that it is conducted in a proper manner and to report any changes that need to be made to the facility contact. The observer should never tamper with any equipment or handle or mark on any operating logs.

It is usually advisable during a trial burn to check the operating parameters on a routine schedule and to note any sudden changes that occur during the test period. Specifically the observer must check to see that the incinerator and control equipment are operating as prescribed in the trial burn plan and must determine if any significant shifts in parameters occur during or between test runs. If shifts do occur, it is the responsibility of the agency to determine the effect on emissions and whether the shifts compromise the representativeness of the test.

The emissions testing will provide the basic data for all control equipment, including gas volume, composition, temperature, and pollutant emission rate. For each control equipment category the final disposition of the collected material should be determined by the observer.

In addition to monitoring operating parameters, the observer must also direct his attention to the sampling team. The observer must ensure that all test procedures are being performed and all quality assurance measures implemented in accordance with the approved trial burn plan. The observer should begin sampling procedure observation from the time the equipment is being unpacked and assembled and the sample recovery area is being readied for use.

Observation of the sampling techniques should confirm that all procedures are performed correctly and all samples are representative. Sample contamination is of primary importance during the trial burn, since ambient levels of contaminants occasionally are quite high relative to the concentrations in the sampled gas streams. Typically, a VOST or Modified Method 5 sampling train (or both) are used during sampling. Observation of each is briefly discussed in the following paragraphs.

As with all test observations, data recording activities must be periodically checked. While it is not necessary for the observer to watch every move the sampling team makes, minimum observations must be made (i.e., either the pretest or post-test leak check should be observed). Organized observation of the sampling procedures can be best attained with the use of checklists for the specific procedures being employed.

Ideally, all components of the VOST should be constructed of Teflon® or glass. Quality assurance measures to prevent sample contamination must be followed at all times. The observer should ensure that a charcoal tube is attached to the sample probe when not in use (i.e., after equipment setup, and during leak checks and sample recovery procedures). Use of an atmospheric glove bag equipped with an open dish of charcoal provides additional assurances against sample contamination. Exposure of a field blank to the atmosphere for the same duration as the sample cartridge will indicate the extent of sample contamination due to ambient conditions. The observer must ensure that the field blank is subjected to conditions similar to those of the sample cartridge.

Observation requirements for Modified Method 5 sampling techniques are similar to those of Method 5; additional information to be monitored includes the condenser exit temperature which must be maintained at or below 20°C. As with the VOST, representative samples will be obtained only if contamination is prevented. A Teflon® septum should be used to securely close the nozzle opening during a leak check, and either

aluminum foil or a Teflon® cap should cover the nozzle when the sample train is not in use. Field blanks should also be used as an indicator of contamination due to ambient conditions. The observer must ensure that field blanks are exposed to the same conditions as the sample, with the exception of not being exposed to the stack gases. Additionally, the XAD traps must be stored at temperatures lower than 50°C when not in use.

To reduce the possibility of invalidating the test results, the responsible person must carefully remove all of the samples from the sampling train and place them in sealed, nonreactive, numbered containers. It is recommended that the samples then be delivered to the laboratory for analysis on the same day. If this is impractical, all samples should be placed in a carrying case (preferably locked), in which they are protected from breakage, contamination, loss, or deterioration.

The responsible person must also mark the sample properly to provide positive identification throughout the test and analysis procedures. The Rules of Evidence require impeccable identification of samples, analysis of which may be the basis for future evidence. Positive identification must also be provided for any filters used in a test. Generally, particulate filters are identified using indelible ink, but, due to the possibility of contamination from the organic constituents of the ink, alternate identification must be employed when using Modified Method 5 sampling train. Finally, each container must be uniquely identified to preclude the possibility of interchange. The number of each container is recorded on the analysis data chain of custody sheets associated with the sample throughout the test and analysis.

While it is often impractical for the analyst to perform the field test, the Rules of Evidence require that a party be able to prove the chain of custody of a sample. The use of standardized data sheets by the tester/analyst as shown in Reference 5 should assist the tester in meeting these requirements.

Potential sources of error in analysis lie in the sampling, the analyzing equipment, the analytical procedures, and documentation of results. Since analysis is often performed at a laboratory distant from the test site, the agency observer usually is not present during analysis. The best method of checking the accuracy of the analytical system is through the use of an audit sample. To ensure proper execution of the required procedures, the observer may request that the analyst complete the appropriate analytical checklist contained in Reference 5.

Observation Report

Upon completion of the trial burn, the observer begins the final task of determining the representativeness of the test data. An observer's report is written for attachment to the test team report. The facility operation data from the field checklists and field notes provide the observer with the information to determine the representativeness of the process and control equipment operation and the sample collection. Minimum conditions must have been met. If the observer suspects a bias in the results, this bias and its direction should be noted. A bias that can only produce emission values higher than the true emissions would not invalidate the results if the incinerator is determined to be in compliance, but should still be noted.

The test team supervisor is generally responsible for compilation of the test report, usually under the supervision of a senior engineer, who reviews the report for content and technical accuracy. Uniformity of data reporting enhances the speed and efficiency of agency review, hence the recommendation that the agency provide a report format and other guidelines to the test team supervisor.

The observer performs the first review of the test report. He should check all calculations and written material for validity, noting any errors and providing any necessary comments. Although the conclusions in the observer's report do not constitute final authority, they generally carry great weight in the final decision concerning the representativeness of the test. Because of the importance of the observer's report and the likelihood that it may be used as evidence in court, the observer should use a standard format that will cover all areas of representativeness in a logical manner. His report review form should parallel the report format provided to the test team leader and may include, if desired, all field notes and checklists.

In addition to the determination of representativeness of the test, the observer reports the conditions under which the facility must operate in the future to maintain their conditional compliance status. These compliance test reports and the conditions of compliance acceptance provide the inspector with sufficient data for conducting future facility inspections.

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Reporting Trial Burn Results

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Introduction

This paper discusses the importance of uniform reporting of information relating to performance of hazardous waste incinerators. The EPA or state permit writer is charged with the responsibility of reviewing all submitted incinerator design, operating and trial burn data and translating this information into enforceable permit conditions. The review of relevant information is often complicated by the lack of formats and incomplete information. Required information may be either lacking or it may be buried in a trial burn report in an inappropriate location. Furthermore, inclusion of redundant or nonimportant information may also delay the review and permit-writing process.

The permit reviewer/writer may face a variety of problems. For example:

- It is not always clear which data are used in calculating the end results.
- Treatment of blank corrections is not uniformly done.
- Not all relevant operating conditions are reported.
- Departures from standard sampling and analysis methodologies are not well documented.
- Quality assurance data are inadequate.
- Significant departures have been taken from the Trial Burn Plan, which may have been written several months previous to the trial burn.

Clearly, there is a need for uniformity both in terms of extent of information and in the logical organization of the information in a manner which makes the permit writer's job easier. This will help to speed up the entire permitting process, thus serving the needs of the regulatory agency, the facility, and the public to make available soundly demonstrated technology to dispose of hazardous waste.

There are several types of reporting needs. First, the permit writer needs the results of performance and operation during the trial burn itself. Additional design data may also be required to perform an engineering analysis to support permit conditions. Finally, the EPA needs both design and performance results for incorporation in its national data base for hazardous waste treatment, the Hazardous Waste Control Technology Data Base (HWCTDB). This data base explores the universe of hazardous waste incinerators in order to judge how well existing technology and regulations are serving the environmental, health, and economic needs of all parties.

It is difficult to develop a single uniform reporting format which will apply to all situations. Indeed, to require such a rigorous format could create unnecessary burdens on incinerator owners and operators and their contractors. However, strong guidance is needed to assure some degree of uniformity. Many times availability of good examples will provide the best guide for a reporting format. Example forms will be available in an EPA guidance document to be released in Spring 1987.

Overview of Trial Burn Data

The trial burn is the key focal point of the entire permitting process for hazardous waste incinerators. The trial burn is actually a series of tests designed to determine if the performance of the incinerator meets applicable standards and to demonstrate that the facility is capable of reliable operations that pose minimal threat to health or environment. The permitting process is generally broken up into three distinct phases: pretrial burn, trial burn, and post-trial burn.

In the first phase, the Part B permit application is written, generally incorporating the Trial Burn Plan. The Trial Burn Plan should reflect careful planning and forethought as to anticipated conditions during the trial burn. The Trial Burn Plan or permit application also provides design data on the facility and other relevant information needed to determine if the unit can be safely operated during the trial burn.

The trial burn is normally the shortest part of the permitting process, but also the most intensive. Over an interval that usually ranges from several days to several weeks, hundreds of samples are taken and an exhaustive

amount of data are collected. Following the trial burn, several weeks or months are needed to analyze all samples and to report data. The manner in which these data are reported is critical to ensure that the permit writer is able to write the best permit conditions for long-term facility operation.

The amount and variety of information that should be included in a Trial Burn Report is extensive. An example format for the main body of a Trial Burn Report is shown in Table 1. This ordering of information represents a logical sequence of results that can be easily followed by the permit reviewer. Other organizational techniques could also be acceptable, however, it is very important that all results needed for permitting be presented clearly and not have unnecessary information interspersed. This is an overview of all information that might be required or otherwise included in trial burn reports; not any one incinerator would have all of the components covered in this matrix. Trial burn data which are normally appended to the main report are shown in Table 2. Additional data may be required in specialized cases.

Some of the data and information reported is specifically required by regulation. Regulations for hazardous waste incinerator permits are found in 40 CFR 270.62. Specific information required in the Trial Burn Report is covered in § 270.62(b)(6) – 270.62(b)(9). These requirements are listed below:

- A quantitative analysis of the trial POHCs in the waste feed to the incinerator.
- A quantitative analysis of the exhaust gas for the concentration and mass emissions of the trial POHCs, oxygen (O_2), and hydrogen chloride (HCl).
- A quantitative analysis of the scrubber water (if any), ash residues, and other residues, for the purpose of estimating the fate of the trial POHCs.
- A computation of destruction and removal efficiency (DRE) ....
- If the HCl emission rate exceeds 1.8 kilograms of HCl per hour (4 lb/hr), a computation of HCl removal efficiency ....
- A computation of particulate emissions.
- An identification of sources of fugitive emissions and their means of control.
- A measurement of average, maximum, and minimum temperatures and combustion gas velocity.
- A continuous measurement of carbon monoxide (CO) in the exhaust gas.
- Such other information as the Director may specify as necessary to ensure that the trial burn will determine compliance with the performance standards ... and to establish the operating conditions required ... as necessary to meet that performance standard.
- The applicant must submit to the Director a certification that the trial burn has been carried out in accordance with the approved trial burn plan, and must submit the results of all the determinations required [above] .... This submission shall be made within 90 days of completion of the trial burn, or later if approved by the Director.
- All data collected during any trial burn must be submitted to the Director following the completion of the trial burn.
- All submissions required [above] ... must be certified on behalf of the applicant by the signature of a person authorized to sign a permit application or a report ....

The reporting requirements include a mixture of facility operation results, sampling and analysis results, and performance results. Certain quality assurance and quality control (QA/QC) results will also be required according to EPA policy.

Data Processing

Permit conditions for a hazardous waste incinerator should assure that the unit always meets the performance standards. The trial burn is a performance test of the system to demonstrate that the performance standards are met under specified operational conditions. Ideally, measuring an incinerator's performance would be done on a real-time basis, however, a certain amount of time averaging must be used in evaluating and reporting trial burn data.

Most of the trial burn data fall into two categories: (1) data representing an average over the test period or portion of the test period, and (2) data recorded continuously or semicontinuously. Data that by necessity represent an average include most of the analytical results (e.g., waste characterization results for a composited sample of waste feed or POHC results for a sampling period of minutes to hours). Data taken continuously (or as continuously as practicable) include both process data and continuous emission monitor (CEM) data. This section discusses primarily how continuously monitored data are processed and reported.

Regulations relating to trial burn reporting require determination of "a measurement of average, maximum and minimum temperatures and combustion gas velocity" and "a continuous measurement of carbon monoxide (CO) in the exhaust gas" [40 CFR 270.62(b)(6)(viii,ix)]. These are the only regulations specifying either statistical measures or frequency of measurement for trial burns. However, other regulations pertaining to monitoring of incinerators require the continuous monitoring of combustion temperature, waste feedrate, the indicator of combustion gas velocity, and CO [40 CFR 264.347(a)(1,2)]. In practice, minimum, maximum, and average values are often reported for other process and CEM data.

Generally, in reporting continuous data, problem areas involve how the data are recorded. Because of the requirements for automatic waste feed cutoff described in 40 CFR 264.345, key process data such as CO, waste feedrate, temperature, velocity, APCE parameters, and draft should be monitored automatically. Newer incinerators tend to be equipped with advanced enough technology so that most instrumental data can be recorded automatically and processed as needed by data loggers and computers. However, many existing facilities rely upon manual recording of data at frequent intervals in the facility operating log. For an operating condition not specifically required to be recorded continuously, manual reading at 15-min intervals is typical.

The frequency at which data measurements are taken and recorded is a primary concern. If automated data logging equipment is used, data which can be continuously monitored should have measurements taken at least every 15 sec and generate an updated value at least every minute. The use of rolling averages over a longer interval (i.e., 5 to 15 min) may be useful. CO is a special case that requires careful attention.

Most process instruments produce nearly instantaneous electrical signals that may be read on a gauge or processed in a data logging system. CEM data, however, are generally not as responsive to changing conditions. This is due to delays caused by a sample of the gas stream physically moving through a probe line and also instrumental delays caused by a sensor which must adapt to changing gas composition. For a given gas, one type of instrument may be inherently more responsive than another. For example, paramagnetic oxygen monitors are much more responsive than electrochemical types.

Combined delays for sample lines, conditioning systems, and instruments may range from several seconds to several minutes. The CEM system may be responsive in "tracking" a small change in concentration, but not be responsive to a large peak or dip. Differences in delay times and responsiveness must be accounted for in comparing data on different parameters.

Another general data quality problem common to most Trial Burn tests involves correlating the performance results with the operating conditions. Different kinds of results cover different time periods throughout the overall Trial Burn test, which may span 6 to 8 hr. The incinerator operating conditions should, of course, be maintained as steady as possible throughout the test period, but unavoidable variations in waste properties and other factors may cause the unit to show some variability throughout the test. An example trial burn test timeline is shown in Figure 1 to illustrate these correlation problems.

For all process and CEM data, the average (arithmetic mean), maximum, and minimum values should be reported for the trial burn test period, as easily read graphical displays can be included for these parameters, with time and units clearly indicated. This will enable the permit writer to assess the variability of the data more easily. The use of rolling averages may also be of value for certain key parameters, particularly CO.

Table 1. Trial Burn Reporting Format

Recommended Report Organization	Specific Information
Preliminary	Certification letter
Preface	Facility name/location Name of company performing testing
Table of contents/lists of tables and figures	
1.0 Summary of Test Results	
• Process operation	Test dates Residence times Combustion temperatures Heat input (firing) rate Summary of APCE parameters Stack height Stack exit velocity Stack temperature Stack excess O_2
• Emissions performance	Test dates DREs Particulate emissions HCl emissions Cl REs Stack gas flow rates O_2 CO_2 CO

Table 1. (Continued)

Recommended Report Organization	Specific Information
2.0 Introduction	
• Background	Brief discussion of incinerator type and design Objectives for trial burn Planned test matrix and deviations Description of wastes/fuels
• Non-standard practices/events	Description of any unusual test methodologies Discussion of any special problems encountered
3.0 Performance Results	
3.1 POHCs	Input rates Emission rates DREs
3.2 Chlorine	Input rates Emission rates REs
3.3 Particulate	Concentrations
4.0 Process Operating Conditions	
4.1 Process Overview	Brief description Process diagram
4.2 Incinerator Operating Conditions	
• Combustion temperature	PCC temperature SCC temperature
• Waste feed/auxiliary fuel data	Brief descriptions/firing locations Feedrates Firing rates Ash loading rates
• Waste burner data	PCC atomization/burner pressures SCC atomization/burner pressures
• Airflow data	Flow rates/velocities from MM5 Flow rates/velocity indications from process monitors Blower data Draft measurements
• Residue generation rates	Bottom ash Fly ash Scrubber mud/solid residue
• Other operating conditions	Kiln rotational speed Other conditions deemed important
4.3 APCE Operating Conditions	
• Wet processes —Quench	Exit temperature Water flowrate
—Venturi scrubber	Pressure drop Water/liquor flowrate
—Packed tower scrubber (adsorber)	Pressure drop Liquor flowrate Effluent pH
—Ionized wet scrubber	Voltage (AC, DC) Current (AC, DC) Sparking rate

Table 1. (Continued)

Recommended Report Organization	Specific Information
—Mist eliminator	Pressure drop
• Dry processes	
—Cyclone	Pressure drop
—Dry scrubber	Reagent flowrate Atomizer rotational speed or nozzle pressure Inlet/exit temperatures
—Baghouse	Pressure drop
—Electrostatic Precipitator	Voltage Current Sparking rate
5.0 Sampling and Analysis Results	
5.1 Methods Description	Summary table Diagram of sampling locations
5.2 Waste Feed and Fuel Characteristics	
• Physical characteristics	Moisture Ash Volatile matter HHV Specific gravity Viscosity
• Chemical characteristics	Chlorine POHCs Other App. VIII compounds Metals
5.3 Stack Gas Concentration Data	
• Gases	
—CEMs	CO CO_2 O_2 SO_2 NO_x TUHC
—Orsat	CO_2 O_2
• POHCs	Volatiles, semivolatiles, other analytes
• Other	Moisture Chloride Particulate Metals PICs/other App. VIII compounds
5.4 APCE Aqueous Streams	POHCs Chloride TDS pH Metals
5.5 Ash and APCE Residues	EP toxicity test results POHCs Metals

Table 1. (Continued)

DRE = Destruction and removal efficiency
RE = Removal efficiency
POHC = Principal organic hazardous constituent
PIC = Product of incomplete combustion
APCE = Air pollution control equipment
PCC = Primary combustion chamber
SCC = Secondary combustion chamber
CEM = Continuous emission monitor
O_2 = Oxygen
CO_2 = Carbon dioxide
CO = Carbon monoxide
SO_2 = Sulfur dioxide
NO_x = Nitrogen oxides
TUHC = Total unburned hydrocarbon
TDS = Tota1 dissolved solids
EP = Extraction procedure

Table 2. Trial Burn Reporting Format—Appended Information

Typical appendix format	Contents
Detailed S&A Results	
• POHCs	Concentration in each sample Sampling durations Trip and field blank values Averages
• Chloride	Concentration Impinger volumes Blank values
• Particulate	Filter weights
• All analytical test results	GC/MS or other printouts
Raw Data Logs	
• Process data	Log sheets, strip charts
• CEM data	Strip charts, printouts
• Stack sampling data	Field data forms
QA Results	Surrogate recoveries Blind audit samples
S&A Methods	Standard method writeup Description of any deviations "Nonstandard" methods
Chromatograms	Waste analysis Emissions analysis

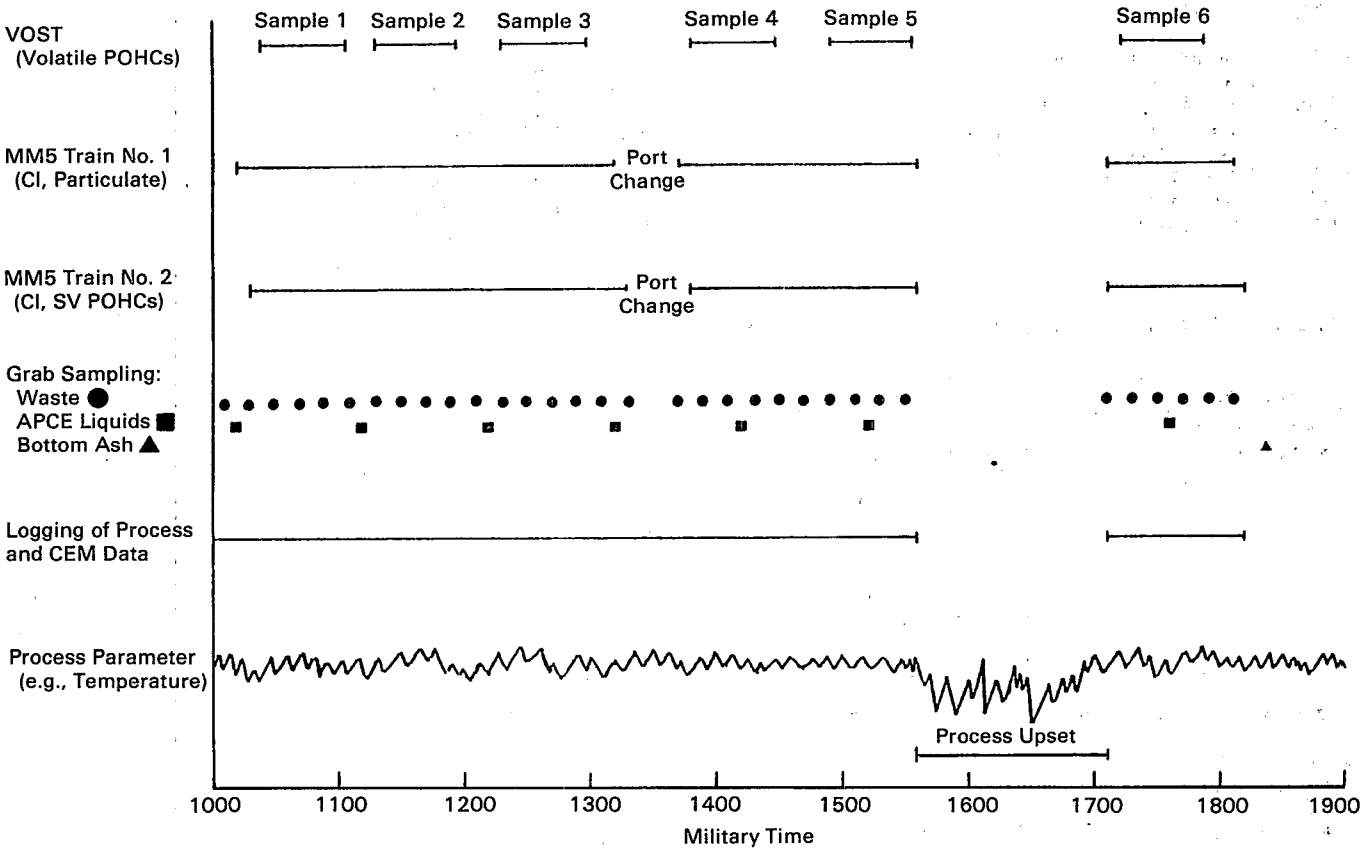

Figure 1. Example trial burn test timeline

Translating Trial Burn Test Results into Permit Conditions

By

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S. Torbov (ACUREX)

Background

RCRA regulations require that owners and operators of hazardous waste incinerators demonstrate compliance with performance standards specified in 40 CFR 264.343. Trial burn test results are the official demonstration of compliance with POHC DRE, particulate and HCl emissions standards. Existing incinerators are permitted by Regional EPA Administrators, or State Environmental Agencies with jurisdiction over hazardous waste management (HWM) facilities, following the completion of the trial burn or submittal of data-in-lieu of trial burn. The permits must specify operating requirements that are aimed at guaranteeing continued compliance plus various general operating conditions. Although limitations for specific operating parameters are required under the regulations (40 CFR 264.345), the Regional and State permit writers must use professional judgement in specifying operational limits for a variety of trial burn test cases. Clearly, this task is difficult considering the complexity of incinerator systems and their operation, the variety of wastes and trial burn cases, and the associated responsibility of issuing permits that safeguard the public's health and protect the environment. Consequently, translation of trial burn data into permit conditions has been laborious and lacking the desired consistency and uniformity among permit writers.

Objectives and Uses

This paper discusses the development of guidance on translating trial burn test results into operating permits for hazardous waste incinerators. The information is preliminary because it is based on an ongoing study to develop a guidance manual on trial burn reporting format and setting permit conditions. This manual will be a companion to other guidance manuals, each addressing specific requirements of the RCRA Part B process including trial burn planning and execution, incineration measurements, and quality assurance/quality control (QA/QC). This paper focuses on the specific steps in the permit condition setting process and the operational limits required to ensure continued incinerator compliance demonstrated during the trial burn.

Admittedly, RCRA requires only regulatory compliance with gas emissions. However, this paper also discusses preliminary guidance to minimize incinerator residual waste emissions in light of anticipated regulations on incinerator residue quality.

Preliminary draft guidance is discussed for selection of key operating parameters, monitoring requirements, and respective operational limits for typical incinerator system components. The selection of key parameters is based on best engineering judgement and sound engineering principles. Graphical presentations of relevant energy and material balance algorithms are also included. Proposed guidance is also given for routine inspection and maintenance of system's components and safety interlock requirements. The information in the final guidance will also be amenable to use by permit applicants to formulate trial burn test plans and by permit writers to provide preliminary feedback to applicants on anticipated permit conditions resulting from proposed test plans. Treatment of trial burn test cases which result in performance failures is not included in this interim presentation but will be available in the final draft of the manual.

Facility Description

The current state-of-the-art in incineration of hazardous waste relies on a well-defined number of thermal treatment and air pollution control equipment options. Thermal treatment equipment usually consists of refractory furnaces capable of incinerating gaseous, liquid, and solid waste in high temperature oxidizing environments. The particular furnace design and waste feed mechanism depend primarily on the physical state of waste incinerated (solids or liquids). The destruction and removal efficiency of principal organic hazardous constituents (POHC DRE), like fossil fuel combustion efficiency (CE), is dominated by temperature, turbulence (mixing), residence time at temperature, and stoichiometry (excess air). Typically, in furnaces where the waste is well mixed with primary fuel and air, the excess air and residence time requirements are lower in order to achieve a given DRE. However, for furnaces incinerating bulk and containerized solids, such as in rotary kilns, the reduced mixing must often be compensated with higher temperature and excess air or

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longer residence time. Consequently, combustion products from rotary kilns are virtually always thermally treated with afterburners or secondary combustion chambers (SCC). Waste destruction in incinerators is a very complex process that is well beyond the capabilities of current analytical predictive models.

Figure 1 illustrates typical incinerator facility layouts. The combustion equipment consists of a primary combustion chamber (PCC), such as rotary kiln or liquid injection incinerators, followed in most cases by SCC equipment. Refractory-lined transition ducting between PCC and SCC units minimizes heat loss. Containerized solids in fiber pack/drums or steel drums are always introduced in the PCC unit (kiln). Steel drums containing solid wastes or other bulk solids are often shredded prior to incineration. Fiber packs or drums are mostly used for containerized sludges, slurries or other semisolid wastes (e.g., gels, resins). Pumpable and atomizable liquid wastes are introduced in both PCC and SCC. Fossil fuels can also be used in both PCC and SCC for initial refractory heatup, combustion stability, and supplemental heat.

Occasionally, a steam generator is used to recover the heat. The heat recovery steam generator does not impact the permit approach unless it is also supplementary fired. For this case, the steam generator can be considered as a tertiary combustion chamber to be treated as a SCC. All commercial and most onsite incinerator facilities treat the gas effluents with air pollution control equipment (APCE). Wet APCE systems are predominant among existing facilities. Operating conditions for these systems are discussed in greater detail in this paper. Figure 2 illustrates a typical wet APCE layout. The gases are cooled in the quench chamber to saturation temperature prior to particulate and acid control in scrubbers and absorption towers. Several scrubber and absorption equipment designs are used. Their performance is governed by a common set of key operating parameters.

Permit Conditions

Figure 3 illustrates the principal steps involved in formulating permit conditions for the operation of the

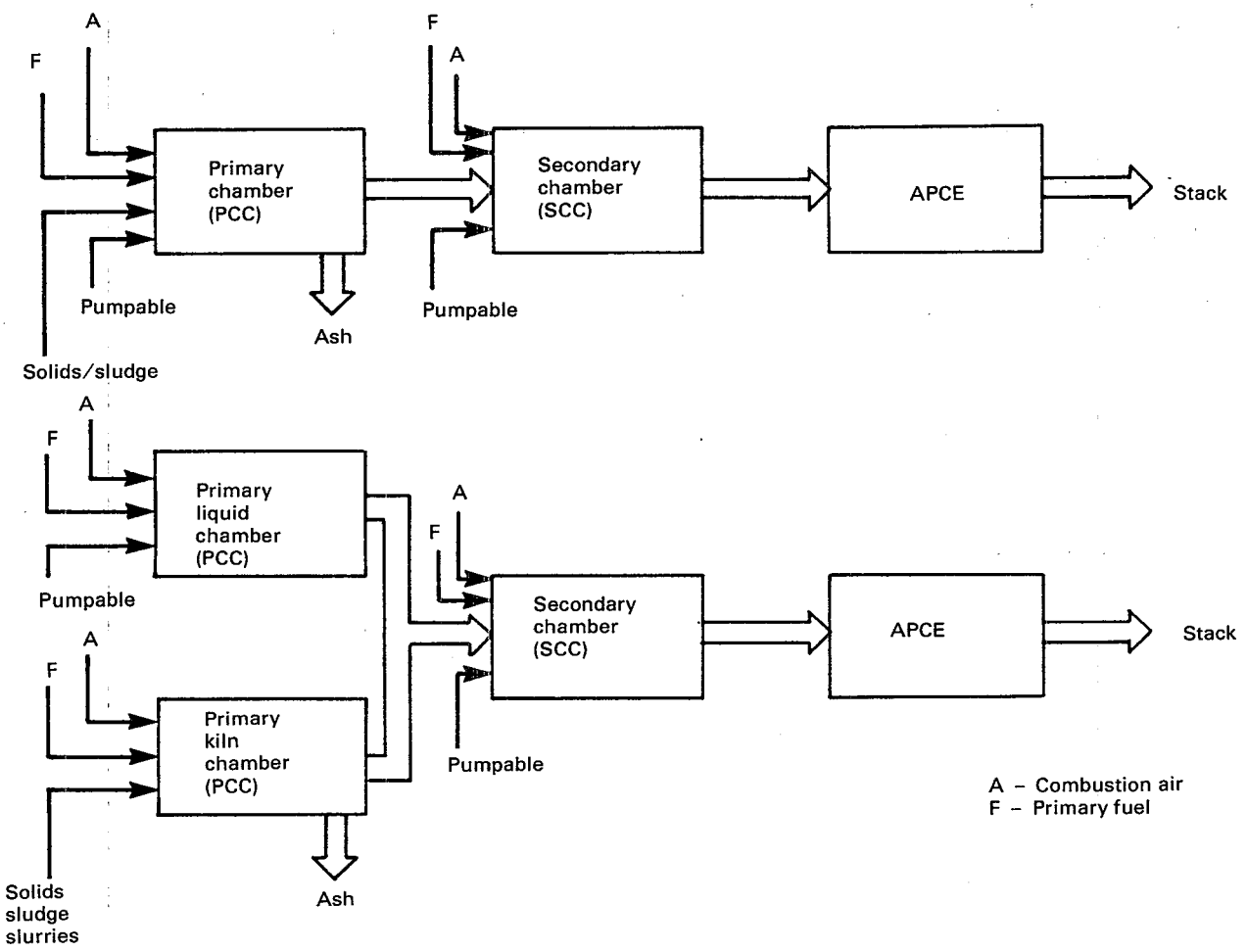

Figure 1. Incinerator equipment arrangements.

incinerator using trial burn test results. The following sections discuss these individual steps in more detail.

Select Appropriate Parameters

Step 1 of the process involves the selection of appropriate parameters that define the system and its intended operation. Key design features of each major system component should be summarized. The particular design features of the system will be used in conjunction with trial burn results to specify operational limits and to perform recommended energy and material balance calculations. Table 1 summarizes the required design information. In general, the information specifies the design capacity of major system components and the design features which impact key process parameters such as gas temperature, residence time, and stoichiometry.

In addition, the permit writer selects appropriate operational, waste, and emission parameters that will form the basis of the operating permit. Test data on each of these parameters should be available in the trial burn report. Table 2 lists possible parameters and their selection criteria. As indicated, specification of some parameters is required under current RCRA regulations while others are recommended for possible inclusion in the permit conditions on the basis of their potential impact on incinerator performance. Since trial burns are typically designed to demonstrate compliance over a range of operating conditions, several settings for each parameter are likely to be available in the report. A particular complication of trial burn results evaluation is that all maximum and minimum settings specified in Table 2 do not always occur during one test condition. For example, the minimum temperature condition may not correspond with the maximum waste feedrate tested thus affecting the specific limitations imposed in the

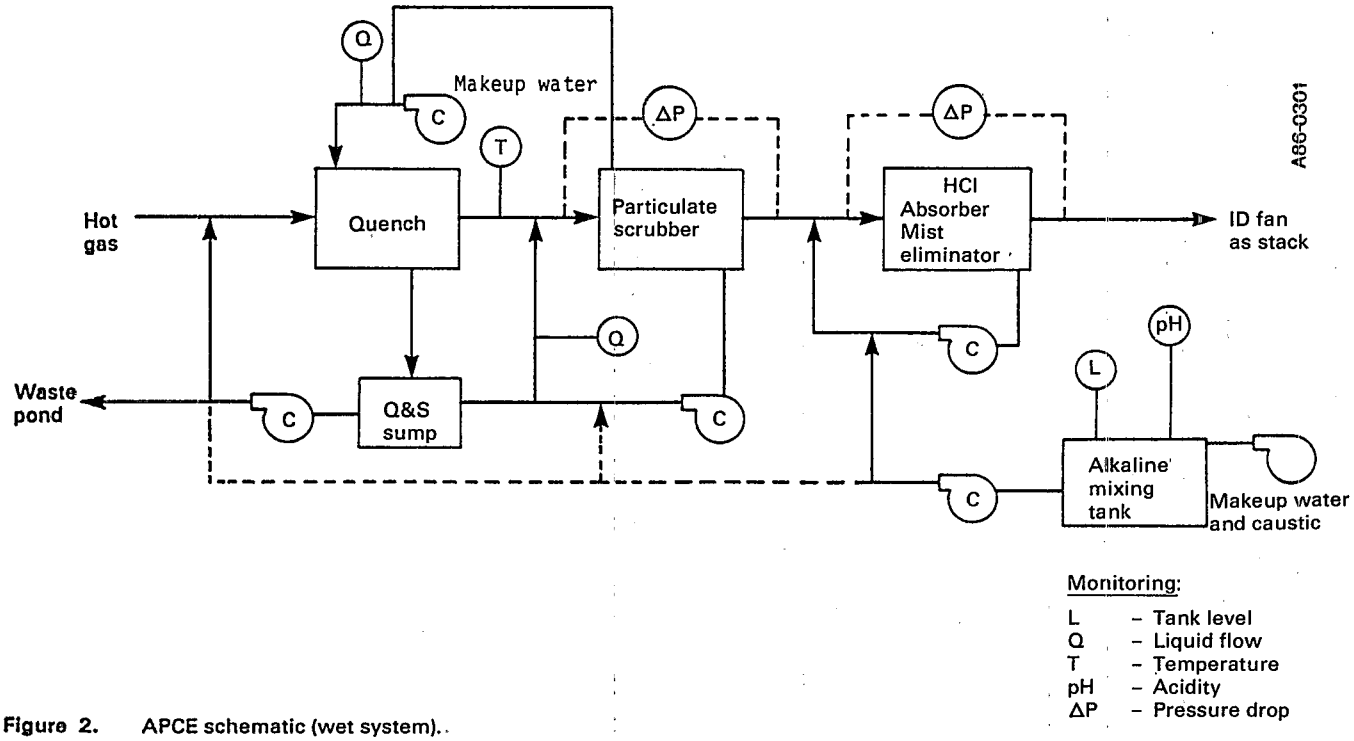

Figure 2. APCE schematic (wet system).

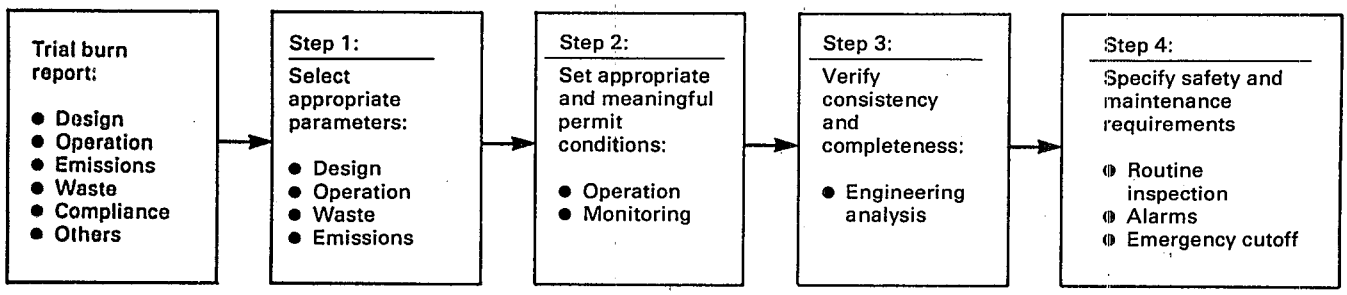

Figure 3. Translating trial burn results into permit conditions.

Table 1. Identify Appropriate Design Parameters

- Incinerator design (PCC and SCC)
  - —Arrangement
  - —Capacity (MBtu/hr)
  - —Internal dimensions, volume (including transition)
  - —Primary fuel type, capacity (MBtu/hr)
  - —Refractory area, thickness and conductivity
  - —Kiln inclination, rotational speed
  - —Waste injection locations
  - —Burner and atomization design
  - —Combustion air capacity (scfm)
  - —Design chamber draft (in W.C.)
- Air pollution control equipment
  - —Types and arrangement
  - —Gas capacity (scfm)
  - —HCl capacity (lb/hr)
  - —Inlet temperature (°F)
  - —Design pressure drop
- Ancillary equipment
  - —Primary gas mover capacity (scfm, ΔP, motor amps)
  - —Quench, scrubber, absorber water capacity and temperature (gpm, °F)

permit. Furthermore, process settings are often not constant requiring that more than one average setting be specified in the permit. For example, continuously monitored and recorded CO emissions, as with gas temperature, are likely to vary over the duration of a trial burn test, requiring specification of rolling time averages as well as appropriate minimum or maximum levels. The POHC concentration in the waste and the waste heating value are not usually considered for permit specification because performance data to date do not support such approach. Furthermore, as long as combustion chamber temperature, residence time, and stoichiometry are maintained at permit specifications with appropriate air and supplementary fuel, the impact on POHC DRE is considered negligible. Limitation on waste heating value, however, may result from incinerator design limitations. Total ash and organic halides feedrates and APCE operating parameters can be selected primarily on the basis of potential impacts on particulate and HCl emissions.

Set Permit Conditions

Tables 3 through 5 summarize the monitoring methods and permit guidelines for process parameters identified in Table 1. For the most part, the tables are self explanatory however, the following sections discuss in more detail some proposed permit guidelines for selected key parameters.

Minimum Temperature

Combustion chamber temperature is a critical process operating parameter. Relatively high temperatures are required for thermal decomposition and oxidation reactions of hazardous organic molecules. The higher the temperature the faster are the decomposition and reaction rates. The maximum combustion chamber temperature is constrained by design considerations such as heat input capacity and refractory limits. The design heat input capacity should not be exceeded to minimize equipment problems. Typically, this is not an important consideration since facilities are not subjected to operation outside manufacturer design specifications. More importantly, the permit writer has to specify a minimum temperature for each combustion chamber outlet. Continuous traces of gas temperatures are reported for each test in a trial burn. Typically, these traces show relatively steady (±2 percent) gas temperatures because of the high thermal capacity of the refractory material. However, some cases of higher temperature fluctuations during a trial burn may also be encountered. The permit condition should address both these cases.

For relatively constant temperature traces the permit writer should specify a time-average temperature. The minimum SCC temperature should be the one recorded during maximum waste feed injection into the chamber (worst case). The permit writer should verify that this minimum temperature can be maintained regardless of waste heating value. For example, if the water content of the waste increases dramatically the total heat input capacity should be such to compensate for the quenching effect of increased water feedrate. If the waste constitutes the primary fuel to the SCC, a minimum low heating value (LHV) of 7000 Btu/lb should also be mandated to guarantee combustion stability. If the minimum average temperature for the SCC is at or below 1650°F (900°C) then automatic waste cutoff to both PCC and SCC limits should be required when the instantaneous SCC temperature falls below the set limit. The rationale is based on thermal decomposition data for oxidative environments which indicate potential DRE failure for several hazardous organic compounds when exposed to lower temperatures for ≤2 seconds (Reference 1). For SCC temperatures of 1740°F (950°C) or higher, a waste cutoff requirement should be set at 98 percent of the average value.

For unsteady temperature traces where the standard deviation exceeds 4 percent of the time-weighted mean, the permit writer should specify an absolute minimum temperature and the length of time permitted at that temperature. This approach is designed to maintain some flexibility consistent with the typical operation of the facility. The automatic waste cutoff is triggered when the temperature falls below the absolute minimum or when the specified times are exceeded for temperatures below time-weighted average or at absolute limits.

Maximum Combustion Gas Flowrate

The permit writer should specify the maximum gas flowrate demonstrated in the trial burn as the operating permit condition. Limits on maximum combustion gas flowrate are aimed at maintaining gas residence time in

Table 2. Selection of Appropriate Process Parameters

Process Parameter	Section Rationale
Combustion Chambers:	
Minimum temperature, each chamber	Temperature is kinetically tied to molecular dissociation and thermal destruction. Required under RCRA.
Maximum combustion gas flowrate	Indicator of gas velocity is required under RCRA.
Combustion chamber draft; primary chamber	Control of fugitive emissions is required under RCRA.
Minimum ash retention time; kiln only	Affects mixing and residence time with potential impact on residue quality.
Maximum total waste feedrate; each chamber	Affects heat and air requirements and potential impact on residue quality; required under RCRA.
Minimum O_2; each chamber exit, and at the stack	Indicator of oxygen availability for thermal oxidation. Required to calculate combustion gas flowrates and residence time.
Maximum waste burner turndown and minimum waste and atomization fluid pressures	Indicator of atomization quality. Waste atomization is critical to evaporation and mixing rates and destruction efficiency.
Emissions and Waste Characteristics:	
Maximum CO; corrected at the stack	Best indicator of mixing, combustion efficiency and PIC emissions; CO monitoring required under RCRA.
Maximum halides input rate	Halides are known flame retardants with potential impact on DRE; impacts acid burden to APCE.
Maximum volatile content of waste solids; kiln only	Prevents localized air-deficient zones in the kiln having potential impacts on DRE and byproduct emissions.
Maximum viscosity of pumpable waste; secondary chamber only	Impacts waste atomization and burner operation.
Maximum ash feedrate; each chamber	Impacts particulate emissions and waste atomization in SCC.
Lowest POHC heating value; each chamber	RCRA does not permit POHCs that are less incinerable than trial burn POHC. Heat of combustion is current measure of incinerability.
APCE:	
Liquor pH	Acid scrubbing capability
Liquor/water flowrate	Impacts L/G and gas temperature for acid and particulate scrubbing; important for venturi particulate collection performance.
Pressure drop; venturi; baghouse	Direct impact on particulate collection; controlled with gas throughput or scrubber throat venturi.
Electrical settings; ionizing wet scrubber, ESP	Affects particulate collection efficiency.
Water/liquor temperature	Combustion gas temperature control; together with flowrate impacts particulate collection.

the combustion chambers at or above those demonstrated in the trial burn. Furthermore, limitations on gas flowrate also impose limits on maximum combustion excess air for a given temperature and maximum waste feedrate. Continuous recording of gas flowrate should be required in the permit using direct gas velocity measurement or indirect ID fan amperage. Direct velocity measurements consist of pitot tube, annubar or venturi tube. The pitot tube and annubar offer a marginal degree of accuracy and are generally plagued by maintenance problems. The retrofit of a venturi tube requires a significant capital investment. Alternative indirect velocity measurements are combustion air flowrate and oxygen level. Combustion air flowrate represents the bulk of the mass throughput in an incinerator especially at high excess O_2 levels. Thus,

Table 3. Monitoring and Permit Setting Guidelines—Operating Parameters

Process Parameter	Monitoring Method	Potential Permit Guidelines
1. Minimum temperature at each chamber exit	Shielded Type K or R thermocouple inserted at least 3 in. in the gas flow. Continuous monitoring with recording tied to automatic waste cutoff.	1. Minimum time-average temperature demonstrated in the trial burn. 2. For average SCC temperature ≤1650°F, automatic waste cutoff when minimum is exceeded. For average temperature ≥1740°F automatic waste cutoff when below 98 percent of average. 3. For unsteady temperature traces also define time below average and absolute minimum temperature and time at that temperature. Waste cutoff when limits are exceeded.
2. Maximum combustion gas flowrate (SCC or Stack)	Pitot tube, annubar, venturi tube, ID fan amperage or combustion air blower with continuous recording tied to automatic waste cutoff	1. Do not exceed maximum trial burn gas flowrate or APCE capacity whichever is lower. 2. Automatic waste cutoff when exceeded for 5 min.
3. Combustion chamber draft	Magnehelic or pressure differential gauge tied to automatic waste cutoff	1. Maintain negative pressure in the primary chamber. 2. Automatic waste cutoff in affected chamber if positive pressure for 15 sec.
4. Minimum ash retention time in the kiln.	Kiln rotational speed meter	1. Do not exceed rotational speed demonstrated in the trial burn when burning solid waste. 2. Do not exceed trial burn maximum solid waste loading.
5. Maximum total waste feedrate to each chamber	Batch and continuous waste feedrate monitoring using appropriate meters, recorders, or operational logs	1. Do not exceed total maximum feedrate as demonstrated in the trial burn.
6. Minimum O_2 at each chamber exit	O_2 continuous recording meter tied to automatic waste cutoff	1. Maintain O_2 levels above those demonstrated during the trial burn maximum waste input test. 2. Automatic waste cutoff for lower O_2 levels for over five continuous min.

Table 4. Monitoring and Permit Setting Guidelines—Emission/Waste Parameters

Process Parameter	Monitoring Method	Potential Permit Guidelines
1. Maximum CO	Continuous monitoring at the stack with recording tied to automatic waste cutoff	1. Maximum 5-min rolling average CO measured during trial burn or 100 ppm (corrected to 7 percent O_2) whichever is higher. 2. Maximum average not to exceed 500 ppm. 3. Solid waste feedrate cutoff when average CO is exceeded. All waste cutoff if CO remains above average for 5 min. Waste feed is renewed after CO is stabilized below average for minimum of 15 min. 4. Automatic cutoff of all wasteload when instantaneous CO exceeds maximum recorded during trial burn

Table 4. (continued)

Process Parameter	Monitoring Method	Potential Permit Guidelines
2. Maximum organic halides feedrate	Perform halides analyses using ASTM D808-81	1. Do not exceed total halides feedrate in each chamber demonstrated during the trial burn. 2. Blend the waste streams or reduce feedrate as appropriate for higher halide concentrations.
3. Maximum volatile content of bulk and containerized waste	Perform volatile analyses using ASTM D1888-78	1. Do not exceed total volatile content in the solids as demonstrated in the trial burn.
4. Maximum viscosity of pumpable waste to SCC	Perform analyses for viscosity of SCC wastes ASTM D445	1. Do not exceed kinematic viscosity and waste feed turndown as required by atomization type. Automatic waste feed cutoff for feed pressure below set limits or loss of automation.
5. Maximum ash feedrate to each chamber	Perform inorganic ash analyses using ASTM D482-80 for solid and liquid streams to each chamber	1. Do not exceed maximum ash feedrate for which particulate emissions standards were demonstrated during the trial burn. 2. Reduce feedrate of waste as appropriate to maintain inorganic ash feedrate to each chamber below trial burn maximum.
6. Lowest POHC heating value to either chamber	Perform volatile organic analyses per SW-846 appropriate methods	1. Do not incinerate waste having a lower heating value POHC (>100 ppm) than trial burn selected POHC.

Table 5. Monitoring and Permit Parameters—APCE Parameters[a]

APCD	Monitoring Method	Potential Permit Guidelines
A. Venturi Scrubber		
1. Inlet gas temperature	Type K thermocouple inserted at least 3 in. in the gas flow. Signal tied to alarm.	1. Maximum temperature of 500°F with alarm when exceeded. 2. Minimum temperature at 220°F with alarm for lower temperature.
2. Pressure drop	Differential pressure meter with continuous recorder and signal tied to alarm	1. Minimum pressure drop demonstrated during trial burn with alarm for lower pressure drop.
3. Scrubber liquor pH	pH meter with continuous recording and signal tied to alarm	1. Minimum pH demonstrated during trial burn. Alarm activated when pH falls below set point.
4. Scrubbing water/liquor flowrate	Rotameter, venturi, orifice meters. Signal tied to alarm	1. Minimum liquid flowrate demonstrated in the trial burn. Alarm tied with measured stack flowrate.
B. Absorber		
1. Water/liquor flowrate and pH	Rotameter, venturi, orifice meters. Signal tied to alarm.	1. Minimum demonstrated during trial burn. Monitoring signal tied to alarm. 2. Minimum pH of return flow interlocked with increase in makeup water flow for lower pH.
2. Alkaline tank pH	pH meter and tank level recorder. Signal tied to alarm.	1. Minimum pH demonstrated during trial burn

[a]Additional information on key parameters for these and other wet and dry control devices can be found in References 2, 3, 4, and 5.

measuring the combustion airflow to each chamber, or the excess O_2, can in some cases be satisfactory alternatives to flue gas flowrate. For constant speed ID fans, the electric motor amps can also be used in lieu of gas velocity measurements. Since pressure differential changes with gas flowrate the permit writer should determine the relative accuracy of the ID fan amps as an indicator of gas flowrate. This can be done using actual data generated in the trial burn. The trial burn data should also be reviewed to ensure that the maximum gas flowrate specified does not conflict with the ability to maintain negative pressure in the combustion chambers. Automatic waste cutoff should be required when limits set on gas velocity or fan amperage are exceeded for 5 min.

Maximum CO Emissions

During incinerator trial burn tests, CO emissions are likely to show drastically different levels and are also likely to fluctuate significantly over the duration of the test. This poses a particular problem for the permit writer in that CO emissions and DRE performance may be seemingly inconsistent (e.g., high CO and acceptable DRE). However, because CO is measure of combustion efficiency and because high CO is typically associated with higher PIC emissions a relatively low CO limit is recommended for the operating permit. A maximum 5-min rolling average of 100 ppm corrected to 7 percent O_2 when measured at the stack should guarantee continued DRE compliance and low PIC emissions. Notwithstanding, the permit writer may want to consider a higher CO level on the basis of the results for the "worst case" lowest temperature, highest waste feedrate and lowest excess O_2. For example, if the "worst case" test shows 5-min rolling average CO of 140 ppm with performance in excess of the standard (DRE >99.999 percent) than this limit should be considered. However, an average of greater than 500 ppm should not be allowed in any full operating permit. Two stages of automatic waste cutoff should be set. Under the first stage, the solid and containerized waste to the PCC is automatically cutoff if the 5-min rolling average is exceeded. The wastefeed should not resume until the CO has remained below the limit for 15 min. This stage is especially recommended if during the trial burn higher CO emissions resulted with higher PCC solid waste feedrate. All waste feed will be cutoff if the 1-hour average limit is exceeded for more than 5 min. The second stage will call for automatic waste cutoff if the instantaneous CO concentration exceeds the maximum level recorded during the "worst case" test condition.

Engineering Analysis

The third step in setting permit conditions involves the engineering evaluation of pertinent design and operating data. The primary objective of this activity is to ensure that operational limits set by the permit writer are internally consistent and not overly constraining thus preventing unnecessary interruptions in waste feedrate and facility operation. The evaluation relies on relatively straightforward calculations using energy and material balance algorithms. The EPA/HWERL in conducting an Engineering Analysis program intended to provide permit writers with the technical tools to perform these computational checks on a routine basis.

Inspection and Maintenance Requirements

A regular inspection and maintenance (I&M) program is critical to the successful operation of the incinerator facility since its objective is to ensure equipment reliability and safety, accurate monitoring, and regulatory compliance. Any hazardous waste incinerator facility is required to adhere to an I&M schedule. The permit applicant has to submit this schedule with the Part B application (40 CFR 264.347). In turn, the permit writer specifies the I&M schedule in the operating permit. Table 6 summarizes a recommended permit approach to the I&M schedule. Incineration equipment and APCE are inspected daily or weekly to verify the operational status. Performance monitoring equipment is subjected to both inspection and calibration. Inspection is most often done on a continuous basis because most are online monitors with continuous response records. Daily inspection of monitors and instrumentation is also recommended. Equipment service should be performed on the basis of manufacturer recommendation. The permit applicant should specify the manufacturer service recommendations for review by the permit writer. The operating permit should also specify that all alarm, waste cutoff and emergency shutdown interlock systems be tested on a weekly basis. Records of compliance with I&M schedules should be maintained in the facility operational daily log.

Authors Note

Future guidance discussed in this paper is meant to assist permit writers in developing meaningful and defensible incinerator permit conditions on the basis of successful trial burn results. The information is not intended to be rigidly applied for all trial burn cases. The authors recognize that permit writers will occasionally face additional test cases and trial burn results which warrant guidance not provided in this paper. The final version of the guidance manual will expand on the information of this paper to provide a more complete approach to permit setting.

Acknowledgements

This study was performed for the Office of Solid Waste (OSW) under the overall direction of Ms. R. Anderson and the technical review of Dr. C. C. Lee of EPA/HWERL in Cincinnati. The results presented were developed with the technical inputs from C. Castaldini and S. Torbov of the Acurex Corporation in Mountain View, California and Dr. R. Seeker of EERC in Irvine, California. Comments and suggestions should be directed to Dr. C. C. Lee in preparation for the manual.

Table 6. Recommended Inspection and Maintenance (I&M) Frequency

		I&M Frequency				
		Operation and Monitoring Equipment			Emergency Systems	
Equipment/Parameter	Conditions	Calibration	Inspection	Service	Alarms	Waste Cutoff
Incinerator Equipment	Operational	—	Daily	1	—	—
Wastefed/Fuel Systems	Operational and Accuracy	2	Daily	1	Weekly	Weekly
PCC and SCC Outlet gas temperature	Operational and Accuracy	Weekly	Continuous	1	Weekly	Weekly
O_2 and CO Monitors	Operational and Accuracy	Daily	Continuous	1	Weekly	Weekly
Gas Flow Monitors:	Operational	Weekly	Continuous	1	Weekly	Weekly
• Direct gas velocity	and Accuracy					
• Indirect fan amps	Accuracy	6 Months	Continuous	—	Weekly	Weekly
Other incinerator monitoring equipment (flame scanners, air blowers, etc.)	Operational	—	Daily	1	Weekly	Weekly
APCE	Operational	—	Weekly	1	—	—
APCE Support Systems	Operational	—	Daily	1	Weekly	Weekly
APCE Performance Instrumentation	Operational and Accuracy	Weekly	Daily	1	Weekly	Weekly

1—Equipment manufacturer recommendation.
2—Equipment manufacturer recommendation or no less than monthly.

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Common Deficiencies in RCRA Part B Incinerator Applications

By

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Introduction

This paper presents information on common deficiencies in RCRA Part B incinerator applications, based on extensive experience at Midwest Research Institute (MRI) in evaluating hazardous waste incinerators and reviewing Part B applications under contract to the USEPA and state agencies. The views expressed in this paper are those of the authors and do not necessarily reflect those of the EPA. Although requirements are listed in the regulations (federal[1] or applicable state) and guidance is provided by EPA,[2-3] certain types of information often are deficient in the applications. The missing information results in deficiency notices and delays in the permitting process.

A major step in obtaining a hazardous waste facility permit is filing a permit application, either a federal "Part B" application sent to the USEPA or an application sent to an authorized state agency. The permit application is a major document containing hundreds to thousands of pages, depending on the complexity of the facility and the number and type of hazardous waste units to be permitted.

In addition to documenting general facility requirements, a hazardous waste incinerator application will include a detailed engineering description of the incinerator and typically a detailed trial burn plan for evaluating the performance of the incinerator. The application will be reviewed by an EPA or state agency permit writer who will issue a "Notice of Deficiencies" with comments on any inadequacies of the permit application. The typical review process may require submittal of one or more revisions of the permit application before all of the permit writers' requirements are satisfied.

A "totally complete" incinerator application is virtually impossible to compile for the initial submittal due to the nature of the permit application review process. With flexibility in the regulations to request all necessary documentation and operating conditions, both to meet the performance standards and to protect the public/environment,[4] the permit reviewer is "grading" each permit application on a case-by-case basis with best engineering judgment. In addition to the specific regulatory requirements and federal, regional, or state policy issues, the case-by-case judgment of individual reviewers makes prediction of all details of information necessary for a complete application very difficult.

Questions Asked by the Permit Reviewer

Even if the exact requirements for an incinerator permit application vary with the agency office and the individual case, the permit applicant can compile a high quality package for the initial submittal by predicting the concerns and needs of the reviewer. In general, the permit reviewer will be asking the following questions:

1. Does the application provide a thorough understanding of how the incinerator works and how it is operated?
2. Is the incinerator safe to test and will it most likely meet the performance standards?
3. Will the proposed test accurately measure the performance of the incinerator for "worst case" operations or over the range of expected operating conditions?
4. Will the proposed test generate the information needed to establish permit conditions for the incinerator?
5. Are the operating protocol and process monitoring equipment adequate on a continuing basis to guarantee operation of the incinerator within the regulatory limits and within the conditions to be specified in the permit?

To answer these questions, the applicant must provide information with an appropriate level of detail in the application.

In addition, the state of the knowledge related to incineration and associated permitting/testing activities is changing as new information becomes available. New

studies continue to provide additional insight into the operation, testing, and performance of hazardous waste incinerators, which creates changes in a permit reviewer's requirements.

The remainder of this paper identifies common deficiencies in recent incinerator applications and suggests an appropriate level of detail for these problem areas based on the authors' experience. The goal is a permit application that receives a "good grade" from the permit reviewer after the first round of review.

Common Deficiencies

1. *Engineering description:* Common deficiencies in this section of the permit application include the following:

   a. Burner/nozzle design—Design specifications of primary importance are: (1) design range of waste feed rate, (2) design range of waste viscosity, and (3) design range of atomization pressure. A comparison of normal/expected conditions and the design specifications is appropriate in the permit application.

   b. Fugitive emission control—The method to control fugitive emissions from the incineration facility and the method(s) used to monitor the control of fugitive emissions must be described in the permit application.

2. *Process monitoring:* During the trial burn, key process parameters must be monitored to characterize the operation of the incinerator. In subsequent regular operations, certain process parameters must be monitored as specified in the permit. The key parameters may include waste feed rate(s), temperature(s), pressure(s), combustion gas velocity or equivalent, carbon monoxide (discussed in more detail below), auxiliary fuel rate(s), waste atomization pressure(s), kiln speed, critical air pollution control device parameters (venturi pressure drop, liquid flow, pH, charging voltage/amperage, etc.), or other parameters depending on the specific facility. Permit applications should contain the following:

   a. A compilation of key process parameters with the type of measuring device, location of device, output (i.e., gauge, digital readout, strip chart, computer, etc.), instrument range and accuracy, expected range, and calibration (method and frequency). A simplified instrumentation diagram may be appropriate.

   b. A list of the process parameters to be monitored during the proposed trial burn, the frequency of readings, and the results to be reported.

3. *Gaseous emission monitoring:* CO must be monitored continuously during the trial burn and during subsequent operation. The adequacy of the CO monitor is an important issue in the permit application. Documentation should include the model and type of monitor; sampling location; type of output; preconditioning system; design and operating range; manufacturers' specifications on accuracy, precision, and sensitivity; and calibration procedures (frequency and method including specification of calibration gases). A diagram of the sampling location and preconditioning system is helpful. (Note: If O_2 monitoring is selected as an alternative to combustion gas velocity monitoring, the above information is also needed for the O_2 monitor.)

4. *Automatic waste feed cutoff system:* The applicant must describe the automatic waste feed cutoff system required in the federal regulations.[5] The permit reviewer expects to find the following information in a permit application:

   a. A general description of the cutoff system including sensing device and action mechanism.

   b. A summary table of parameters monitored in the system and proposed set points.

   c. Discussion and schedule of calibration/testing of the system.

In addition to the parameters specified in the regulations,[6] automatic waste feed cutoff may be required for additional key parameters on a case-by-case basis. Automatic cutoff may be appropriate for low waste feed atomizing pressure; low scrubber water flow, pressure drop, or pH; or other operating conditions posing special performance or safety concerns.

5. *Waste characterization:* To answer the five major questions discussed earlier, the permit reviewer must have complete waste characterization data. Specific needs include content of the Appendix VIII hazardous organic constituents in the waste, chlorine and ash content, heating value, and viscosity (if applicable). This information is particularly important to the reviewer for an understanding of incineration operations, a preliminary evaluation of system performance, and the selection/approval of principal organic hazardous constituents (POHCs) for the trial burn. The applicant must distinguish any differences in waste characterization between the wastes proposed for the trial burn and the wastes incinerated during normal continued operation.

6. *Sampling and analysis:* Some of the most complicated technical questions associated with the permitting of a hazardous waste incinerator are related to sampling and analysis for the trial burn. In most cases, the applicant will require the services of experts who understand the special needs and problems to be addressed in a trial burn sampling and analysis plan. Permit reviewers look for the following items in an application:

a. A detailed summary of the sampling and analysis protocol (i.e., number of samples, sampling locations, sampling intervals/duration).

b. Sampling and analysis of *all* input and output streams associated with the incinerator. (A trial burn test is, amongst other things, a determination of the fate of selected hazardous organic constituents in the incineration facility.)

c. The use of appropriate and proven sampling and analysis procedures. Certain facilities, conditions, or constituents may create special sampling and analysis problems. Documentation of each procedure to be used is necessary in the permit application.

d. Although not required in the regulations, sample calculations are desired to indicate that the proposed sampling methods, sample volume, and analytical detection limits are adequate to determine a destruction and removal efficiency (DRE) of at least 99.99%.

e. A summary of results to be reported and the units.

7. *Quality assurance/quality control:* QA/QC is an essential component of any sampling/analysis activity. A site-specific QA/QC plan typically is required in a trial burn plan. Since the required level of QA/QC will vary with the specific agency or permit reviewer, a preliminary discussion of QA/QC requirements with the reviewing agency is advisable prior to submittal of the permit application.

The combustion sampling manual prepared by A. D. Little[7] includes a discussion of QA/QC procedures. Also, three E PA reports[8-10] provide guidelines on QA/QC plans, but the level of effort discussed may be more detailed than necessary for most incinerator trial burn tests. Table 1 presents a checklist of the contents of a typical QA/QC plan; Table 2 summarizes some of the practical concerns of incinerator testing that are appropriate for a QA/QC plan.

General Considerations

Submitting an incinerator permit application is similar in some ways to turning in a term paper to a college professor. Organization, clarity, and logic may be as important as content. Many of the deficiency comments contained in a Notice of Deficiencies are the result of misunderstandings due to vague or conflicting information presented by the applicant, an expression of the reviewer's frustration of failing to find essential information among thick volumes and appendices of superfluous information, or simply a note of failure to understand the applicant's reasoning for selecting a particular operating scenario. Common sense in compiling a complete and concise permit application can result in fewer deficiency comments and a quicker review process.

Table 1. QA/QC Checklist*

	Sampling	Analysis	Reporting
Technical responsibility	●	●	●
QA responsibility	●	●	●
Quality objectives	●	●	
Quality control procedures			
Equipment calibration	●	●	
Sample traceability/ custody.	●	●	
Blanks	●	●	
Control checks		●	
Internal standards		●	
Surrogates		●	
Replicates	O	●	
Data review	●	●	●
Quality assurance procedures			
System audits	O	O	O
Performance audits	O	●	
Written SOP	●	●	●
Documentation	●	●	●
Corrective action			
Responsibility	●	●	●
Action levels	●	●	●

*R. M. Neulicht, Midwest Research Institute, Personal Communication, November 1985.

O = Optional.

Table 2. Practical Concerns for a Trial Burn QA Plan[a]

- All equipment used in S&A activities should have written calibration procedures. Procedures amd documentation of the most recent calibration should be available.
- Traceability procedures (not necessarily chain-of-custody) should be established to ensure sample integrity.
- A GC/MS performance check sample should be analyzed each day prior to sample analysis. If results are outside acceptable limits, samples should not be run.
- All samples from at least one run should be analyzed in triplicate to assess precision.

- A minimum frequency of check standards (5% is suggested) should be used with each sample batch. Analysis of actual samples should be suspended if check standards are outside of the desired range.

- Blank samples should be analyzed to assess possible contamination and corrective measures should be taken as necessary. Blank samples include:

  —*Field blanks*—These blank samples are exposed to field and sampling conditions and analyzed to assess possible contamination from the field (a minimum of one for each type of sample preparation or the number specified by the appropriate method).

  —*Method blanks*—These blank samples are prepared in the laboratory and are analyzed to assess possible laboratory contamination (one for each lot of samples analyzed).

  —*Reagent and solvent blanks*—These blanks are prepared in the laboratory and analyzed to determine the background of each of the reagents or solvents used in an analysis (one for each new lot number of solvent or reagent used).

- Field audits and laboratory performance and systems audits may be included in some cases. Cylinders of audit gases for volatile POHCs are available from EPA.

- A minimal level of calculation checks (e.g., 10%) should be established.

*Gorman, Paul G., et al., *Practical Guide - Trial Burns for Hazardous Waste Incinerators,* Prepared by Midwest Research Institute for USEPA Contract No. 68-03-3149, Work Assignment 12-7, Final Report, June 1985.

Summary

By understanding the technical and regulatory concerns of regulatory agencies in the permitting of hazardous waste incinerators, an incinerator permit applicant can compile a permit application that requires only minimal follow-up review. Practical considerations can reduce the expense and delays often associated with the permit application review and revision process.

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Indicators of Incinerator Performance

By

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Background

Incineration systems are required to meet the performance as established by the State and the U.S. Environmental Protection Agency (EPA) regulations. Basically for a hazardous waste incinerator, these include the ability of the unit to meet 99.99% destruction and removal efficiency (DRE); the ability to reduce HCl emissions by 99% or a maximum of 4 lb/hr in the smaller units; and the ability to reduce the particulate emissions to 0.08 gr/dscf corrected to 7% oxygen in the stack. Based on the types of waste, the type of incinerator and the type of controls, there are variables in the conditions under which the units operate which will affect the ability of the incinerator to perform to the requirements above.

The major variables in the performance of an incinerator are the following:

Temperature
Pressure
Flow
Flue Gas Composition
Waste Analysis
Ash Analysis

Listed in the handouts provided at the meetings are the variables as listed above, locations for measurement and the means of measuring. The minor incinerator variables are as follows:

Atomizing Fluid Temperature
Amperage
Viscosity
Humidity
Ambient Temperature
Barometric Pressure
pH of Scrubber Discharge
Flame Appearance

The various items listed are covered on separate sheets to show the location of the measurement of the variable, the means of measurement and the effect on the variable whether it is below or above the set point.

Summary

The selected variables for either major or minor conditions within the incinerator which affect the incinerator operation have been covered. In some cases, these may swing from a minor to a major depending on the type of installation or the type of incinerator system. The above are meant to assist in the review of an incinerator permit or Trial Burn to determine which should be looked at carefully when determining whether an incinerator is operating to reach the conditions required by the regulations.

Monitoring Equipment and Instrumentation

By

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Introduction

One of the most important aspects to consider in conducting a trial burn is the selection of the instruments, equipment, and methods used to obtain the data on which a regulatory decision is made. Without accurate and reliable data, a decision is impossible. In this paper in the workshop, the key factors that must be considered in selecting equipment and methods are discussed. Also included is a listing of those instruments, equipment, and methods that are commonly used in test burn sampling and analysis. The purposes of each instrument is briefly outlined as well as possible alternatives. The tables that summarize the information also include a brief overview of information describing advantages and disadvantages of each piece of equipment. A detailed description of each type of measurement and its associated equipment is not possible in this brief paper, but the paper attempts to highlight key areas to be considered in a selection of the various alternatives. Finally, the paper concludes with a brief overview of Quality Assurance/Quality Control (QA/QC) considerations that should be factored in whenever a sampling and analysis or test plan is evaluated.

A list of acronyms and abbreviations used in the paper can be found at its conclusion.

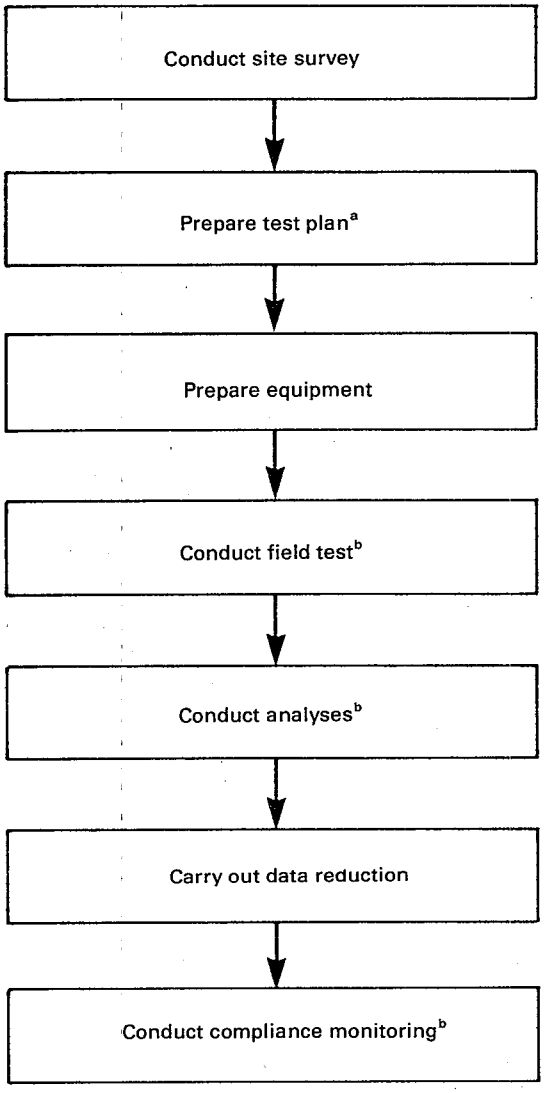
Factors Affecting Instrument and Equipment Selection

Several factors determine the choice of sampling and analysis methods, instruments, and equipment. The primary ones include (1) regulatory requirements, (2) monitoring purpose, (3) unit operating range, (4) waste composition, (5) available sampling methods, (6) analytical sensitivity, (7) QA/QC needs, and (8) economics. These eight factors all play a role in the decision process and, depending upon the particular burn in question, may assume greater or less importance. Clearly, many of these factors are interrelated.

Regulatory requirements are the prime factors which dictate the choice of the sampling and analytical methods. These determine what measurements must be made, since it is the purpose of the test burn to obtain regulatory approval of the use of the incinerator. Based on objectives which are established by the permit applicant, the monitoring purposes can be determined. The operating range of the unit and the composition of the waste fed to it during the test burn influences the specific choice of instruments or monitoring methods. Given that a particular type of measurement must be made, there may be several alternative ways of obtaining this information. The composition of the waste and unit operating range are two of the more significant factors in determining what instruments are chosen. Especially when the EPA is involved, it is preferable that either EPA standard or equivalent methods be utilized if possible. The analytical sensitivity of the instruments and QA/QC needs also should play a factor in the decisions with respect to methods. If the required measurements cannot be made with the necessary quantitation limits needed to establish the effectiveness of the combustor, the type of sampling may need to be changed or perhaps the existing methods modified so that a different size sample may be collected. A final consideration is that of economics. Conducting a test burn is an expensive proposition; the sampling and analysis aspects of the burn are not insignificant contributors to the total cost.

Many questions have to be addressed before a test burn plan can be evaluated. Normally these are considered in the sequence shown in Figure 1. Figure 1 indicates those points in the process where monitoring and instrumentation requirements should be specified and also indicates those points where monitoring and instrumentation equipment are used. It is not crucial that these areas be covered in initial permit applications; however, prior to permit approval, this information must be made available by the permit applicant.

This information would be typically presented in the test plan for the burn. In the test plan the applicant should discuss how the regulatory requirements determine the emission limits and analyte selection for the burn. The description of the system should result in an identification of sampling locations, sample types, and the sample matrix. A discussion of waste and fuel characteristics should dictate what analytes are to be sampled and measured, determine the instrumentation to be used, and dictate the methodology chosen. The test matrix itself should dictate the range of operating conditions. The section on sampling and analysis should



[a]The task where monitoring and instrumentation requirements are specified.

[b]The tasks where monitoring and instrumentation equipment is used.

Figure 1. Flow diagram for testing a hazardous waste thermal destruction device.

identify the species to be measured, the methods to be used to sample or monitor these species, and the analytical methods to be used to characterize the samples obtained. A discussion of QA/QC should include a description of the sampling and monitoring frequency within an individual test, as well as the number of tests to be replicated if this is to occur. It also should include a description of analytical repetition, blanks, standards, and spiking considerations. Finally, the QA/QC section should also specify the calibration and maintenance procedures to be followed for all the instruments. If samples are not to be analyzed onsite, then the QA/QC section should also include consideration of such factors as chain of custody, recordkeeping, and possibly sample transportation and storage. It is usually desirable, although not necessarily essential, that the QA/QC section or the test plan include some description of data validation and review procedures.

Description of Monitoring and Sampling Instrumentation and Equipment

For the purposes of this discussion, equipment and instrumentation are divided into three categories: continuous monitoring instruments; sampling equipment; and analytical instrumentation. All three of these may be used onsite, while analytical instrumentation may also be used at an offsite laboratory.

Table 1 contains a description of continuous monitoring instrumentation. These types of instruments normally monitor for the parameters CO, CO_2, O_2, TUHC (total unburned hydrocarbons), SO_2, and NO_x. Only CO and O_2 are required to be monitored under the Resource Conservation and Recovery Act (RCRA) although, generally, information on the other species is desirable. As can be seen from Table 1, there are several alternatives for the measurement of each of these gases. All are designed to operate on a real-time basis approximately over the range that is presented in Table 1. In Table 2 are several brief comments with respect to the properties of these instruments that may influence their choice for measurement purposes. This discussion is based on instrument type rather than each specific analyte and instrument.

In Table 3, a listing of typical source sampling methods is presented. In most cases these involve stack sampling trains which collect multiple samples. For instance, a particulate sample may be collected at the same time an impinger is collecting a volatile gas. A resin cartridge may collect a sample at the same time as some other factor is being monitored. Most, but not all, of these methods are EPA standard methods; but, unlike the continuous monitors, there is not a lot of choice between them. This is especially true in the case of volatile organics, where the volatile organic sampling train (VOST) is presently the method of choice or, in the case of the Modified Method 5 (MM5), for semivolatile organic compounds and particulate matter.

Once a sample is collected, it is necessary to have it analyzed. The relationship between the samples described in Table 3 and the analytical methods is shown in Table 4. In Table 4 the method is identified, as well as the type of sample that is collected from it. The specific analyte that may be associated with that substrate is indicated. In general there is usually more than one way to quantify a given analyte. This is shown more specifically in Table 5 where a comparison of the most common analytical instruments and/or detector systems are described. For the organic area especially, there is a large range of possible methods or instruments that can

Table 1. Continuous Monitoring Instrumentation

Analyte	Method	Range ppm	Range Percent
CO	NDIR	0.5	50
	Differential adsorption	1	100
	Polarographic	0.01	20
	Spectrometric	1	50
CO_2	NDIR	0.5	50
	Polarographic	0.1	0.1
	Spectrometric	1	50
O_2	Polarographic	0.01	20
	Electrocatalytic	0.1	25
	Paramagnetic	0.1	100
	Spectrometric	1	50
TUHC	FID	0.1	1
	NDIR	10	10
SO_2, NO_x	NDIR	0.5	50
	Polarographic	0.01	20
	Differential adsorption	1	100
	Spectrometric	1	50

be used. A detailed discussion of the capabilities of all of these instruments is beyond the scope of this paper; however, Table 5 does summarize some of the advantages and disadvantages of them. In a review of a test burn sampling and analysis plan, the permit applicant must give some consideration to the parameters to be measured and the means by which these measurements are to take place in the laboratory.

An additional area where measurements are required is in the area of waste characterization. The type of waste fed to the combustor dictates the nature of the measurements that are made. The same instruments that are discussed in Table 5 are also those that are used to characterize the waste fed to the incinerator. The major problem ordinarily is the waste is of a higher concentration than the samples received from the sampling effort. The result is additional analytical steps may be necessary to provide an accurate analysis.

Quality Assurance Considerations

All sampling analysis plans or test plans should contain a section that discusses quality assurance. Preferably, a detailed quality assurance project plan will be prepared for the test burn; however, this is not a requirement. It is key that the plan contains some mechanism to estimate data quality. Typically, the Agency prefers to see some discussion of precision, accuracy, representativeness, completeness, and comparability; although the latter two are not always necessary. It is also key that there is some independent cross-checking of the results that are obtained.

Typically, a quality assurance plan should contain some discussion of chain-of-custody and reporting requirements during all phases of the test. Second, it is a good idea if it contains a discussion for data quality goals because it is these that establish the measurement criteria and equipment decisions. Failure to meet goals impacts the regulatory approval of the future use of the combustor. There should be a discussion of quality control activities as they relate to the sampling and analysis activities of the project. A discussion of data quality assessment and how the data are to be validated is appropriate. Data review procedures, corrective action procedures, and preventative maintenance procedures should also be discussed. Finally, it is desirable, although not essential, that a separate section be included in the final report that discusses QA and QC. In reviewing a proposed test burn plan, or the results of a test burn, it should be kept in mind that quality assurance considerations influence the choice of instruments and

Table 2. Comments on Different Continuous Monitoring Instruments

	Advantages	Disadvantages
NDIR instruments	Moderate cost; can be used several gases	Separate instruments for each gas Subject to interferences Not good with corrosive gases May have limited sensitivity
Polarographic analyzers	Can be used for several gases	Sample gas must be conditioned Electrochemical cell must be replaced every 6 months
Electrocatalytic O_2 analyzer	Both extractive in situ designs	CO, hydrocarbons will burn at device operating temperature Requires stable temperature
Paramagnetic O_2 analyzer		Needs stable gas composition, UHC may react H_2O and particulate matter must be removed NO and NO_2 may interfere

Table 3. Typical Source Sampling Methods

Generic Name	Analytes	Time/ Sample (min)	Volume (l)	Detection Limits	Compound Boiling Point (°C)	Comments

Table 4. Relationship Between Sampling and Analytical Methods

Sampling Method	Substrate Source	Analyte	Method (instrument)
Method 5	Filter	Metals	AA, ICAP
		Weight of particulate matter	Balance
	Impingers	Volatile metals	AA, ICAP
		Anions	Ion chromatography
		pH	pH meter
Modified Method 5	Filter	Metals	AA, ICAP
		Weight of particulate matter	Balance
	Resin	Semivolatile organic compounds	GC/MS or GC (various detectors)
SASS	Filter	Metals	AA, ICAP
	Cyclones	Weight of particulate matter	Balance
	Resin	Semivolatile organic compounds	GC/MS or GC (various detectors)
	Impingers	Volatile metals	AA, ICAP
		Anions	Ion chromatography
		pH	pH meter
VOST	Resin	Volatile organic compounds (VOCs)	GC/MS or GC (various detectors)
VOC (M25A)	Gas	Hydrocarbons	GC
	Condensate	Hydrocarbons	GC
Bag	Gas	Semivolatile organics	GC/MS, GC
		VOCs	(various detectors)
Cryotrap	Condensate	Semivolatile organics	GC/MS, GC
		VOCs	(various detectors)
Andersen	Filters	Size fractionated Particulate	Balance
		Metals	AA, ICAP
		Anions	IC

equipment used for sampling and analysis. The requirements for calibration and the standards that are used for the test also influence the quality of data from the test burn. The number of tests, the number of replicates of each test or burn condition, and the number of replicates of analyses to be made from the samples obtained are dictated by QA/QC considerations. When there is too little QA/QC information, the decision making process is hindered. It should be noted that each test burn is a dynamic situation in which the acquisition of an exact duplicate is never possible; however, it is possible to repeat operating conditions and get some idea of the range of performance of the unit. In some cases, it is also possible to split samples for analyses purposes, even though the sample itself is unique. For example, an XAD resin once extracted may yield an extract which can be analyzed by a gas chromatograph/mass spectrometer more than once.

Summary

As can be seen from the brief discussion of this paper, a permit applicant has a number of things to consider in his or her choice of sampling and monitoring equipment for analytical instrumentation. First, there are the factors that flow from the test burn itself such as the regulatory requirements, the operating range, and the objectives of the burn. Second, there are the limitations or characteristics of the sampling and monitoring

Table 5. Comparison of Analytical Instruments/Techniques

System	Advantages	Disadvantages
GC/FID	Universal, fair sensitivity, wide range	Many interferences, poor sensitivity for RCL and RN, requires specific standards
GC/ECD	Selective for RCL and RN, excellent sensitivity	Easily upset, water sensitive, narrow range
GC/HALL	Selective for RCL, moderate range good sensitivity	Unstable, water sensitive
GC/PID	Selective for aromatics, moderate range, good sensitivity	Limited selectivity, poor sensitivity for RCL
GC/TCD	Universal, wide range	Not sensitive, requires specific standards
GC/MSD	Universal, high identification confidence	Labor intensive, limited selectivity, moderately expensive
GC/MS	Universal, excellent identification, moderate range	Difficult to maintain, expensive, slow, identification range must be sacrificed for sensitivity
HPLC/UV/ FLUOR/RI	Selective/moderate specificity, heavier compounds	Few established methods, labor intensive, moderate cost
HPLC/MS	Universal, heavier compounds, identification	Labor intensive, expensive, experimental
AA	Good sensitivity, specific	Labor intensive, slow, subject to interferences
ICAP	Fast, multielement, can handle oils and other difficult samples	Subject to interferences
IC	Fast, multi-analyte	Columns need frequent replacement

equipment used. Third, there are the limitations of the laboratory instrumentation used. All of these areas must be considered in evaluating a permit or the results from a test burn, for it is on them that the ultimate decision considering the granting of a permit must rely.

List of Acronyms and Abbreviations

AA	Atomic absorption
ECD	Electron capture detector
FID	Flame ionization detector
Fluor	Fluorescence
GC	Gas chromatography
HPLC	High performance liquid chromatography
IC	Ion chromatography
ICAP	Inductivity coupled argon plasma spectrometry
M5	Method 5
MM5	Modified Method 5
MS	Mass spectrometry
MSD	Mass selective detector
NDIR	Nondispersive infrared spectrometry
PID	Photoionization detector
QA	Quality assurance
QC	Quality control
RI	Refractive index
RCL	Organic compound containing chlorine
RN	Organic compound containing nitrogen
SASS	Source assessment sampling system
TUHC	Total unburned hydrocarbons
TCD	Thermal conductivity detector
UHC	Unburned hydrocarbons
UV	Ultraviolet
VOST	Volatile organic sampling train
VOC	Volatile organic compound

Carbon Monoxide Monitoring Guidance

By

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Introduction

As an indicator of combustion performance, continuous monitoring of the carbon monoxide (CO) level in the stack exhaust gas is required for all RCRA permitted hazardous waste incinerators. Furthermore, RCRA requirements stipulate that the permit specify an operating limit for the CO in the stack gas. However, RCRA regulations do not provide specific guidance on monitoring system requirements nor on establishing permit limitations. This paper discusses several aspects of continuous monitoring for CO including (a) system design performance criteria and evaluation, (b) operation/maintenance, (c) data handling, and (d) data evaluation with regards to permit conditions.

Currently, a guidance manual entitled "Guideline for Continuous Emission Monitoring of Carbon Monoxide at Hazardous Waste Incinerators" is being prepared for the EPA Office of Solid Waste (OSW) by Pacific Environmental Services (PES). This document which is expected to be completed in the spring of 1987 will provide specific guidance for many of the issues discussed in a general sense in this paper.

System Design

The RCRA regulations do not specify any design requirements for the continuous emission monitoring system. Consequently, system design is entirely up to the owner/operator.

In fact, "continuous" is not actually defined in the regulation and has been a point of discussion. Although some systems continuously take a sample, most (if not all) "analyze" the sample and transmit the signal at discreet intervals; this interval may vary from less than a second to minutes. The current agency guidance is that an acceptable system will continuously sample the gas and will analyze and transmit a signal every few seconds. That is, a system which analyzes the stack gas every 5 min is not acceptable.

Two general types of systems are available and both have been used on hazardous waste incinerators; these are *in situ* and extractive systems. An *in situ* system actually measures the carbon monoxide concentration in the duct or stack without removing a sample. Typically, an *in situ* carbon monoxide monitor consists of a nondispersive infrared (NDIR) analyzer directly mounted on the stack or duct. The NDIR source is transmitted across the stack, and the amount of NDIR attenuation due to the CO concentration in the gas is measured by a detector. An extractive system removes a gas sample and transports it to a remote analyzer. Each type of system has its advantages and disadvantages. Figure 1 schematically shows the two types of systems. Table 1 presents some of the advantages and disadvantages of each system type.

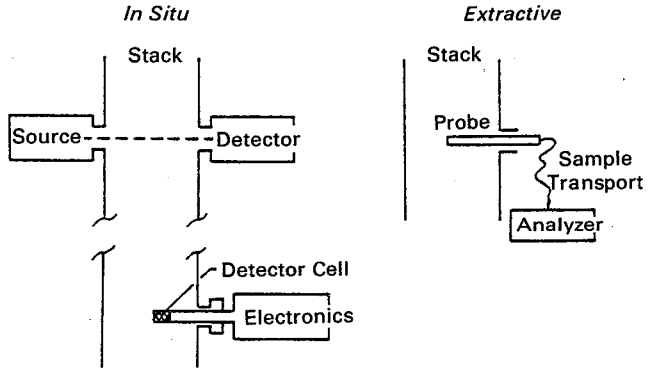

Figure 1. *In situ* and extractive monitors.

The concept of a continuous monitoring system is stressed because the monitoring of carbon monoxide levels incorporates an entire system and not just an "analyzer." A monitoring system includes the following subsystems:

a. Sample interface/transport
b. Sample conditioning
c. Analyzer
d. Data recording
e. Calibration

All aspects of the system are important and must function properly if accurate results are to be obtained. Figure 2 is a schematic of an example extractive CO monitoring system.

Several factors to keep in mind when designing a system are:

Table 1. Some Advantages and Disadvantages of *In Situ* and Extractive Monitors

	In Situ	Extractive
Advantages	• Very rapid response time • No conditioning system • Measures entire stack traverse	• Analyzer can be located in a remote clean area
Disadvantages	• Susceptible to problems from vibration on stack • General inability to directly audit calibration with cylinder gases • Inaccessibility for maintenance	• Complex sample conditioning may be necessary

1. Sampling/measurement location. Obviously, a representative sample must be obtained in order to achieve meaningful results. A sample may be taken from the "hot zone" or following the combustion chamber in the stack or at a location anywhere in between. The advantages of sampling from the hot zone are few. First, since the sample is taken right after the combustion chamber, information on the combustion process is more readily obtained, i.e., the lag time for the emissions to reach the stack is eliminated. Second, the effect of excess air in-leakage into the system downstream of the combustion chamber is minimized. The main disadvantage of hot zone sampling is that the sampling environment is very adverse, i.e., the monitor must sample a hot, corrosive, and dirty gas. This presents serious problems and, in my opinion, a location downstream of the pollution control system is preferable. A single point sample generally is adequate unless the sample is taken immediately following a source of air in-leakage where stratification in the gas stream may occur.

2. Locate the monitoring system parts which require routine maintenance (e.g., filters) in an easily accessible location.

3. Design a data recording/logging system which is useful to the operator.

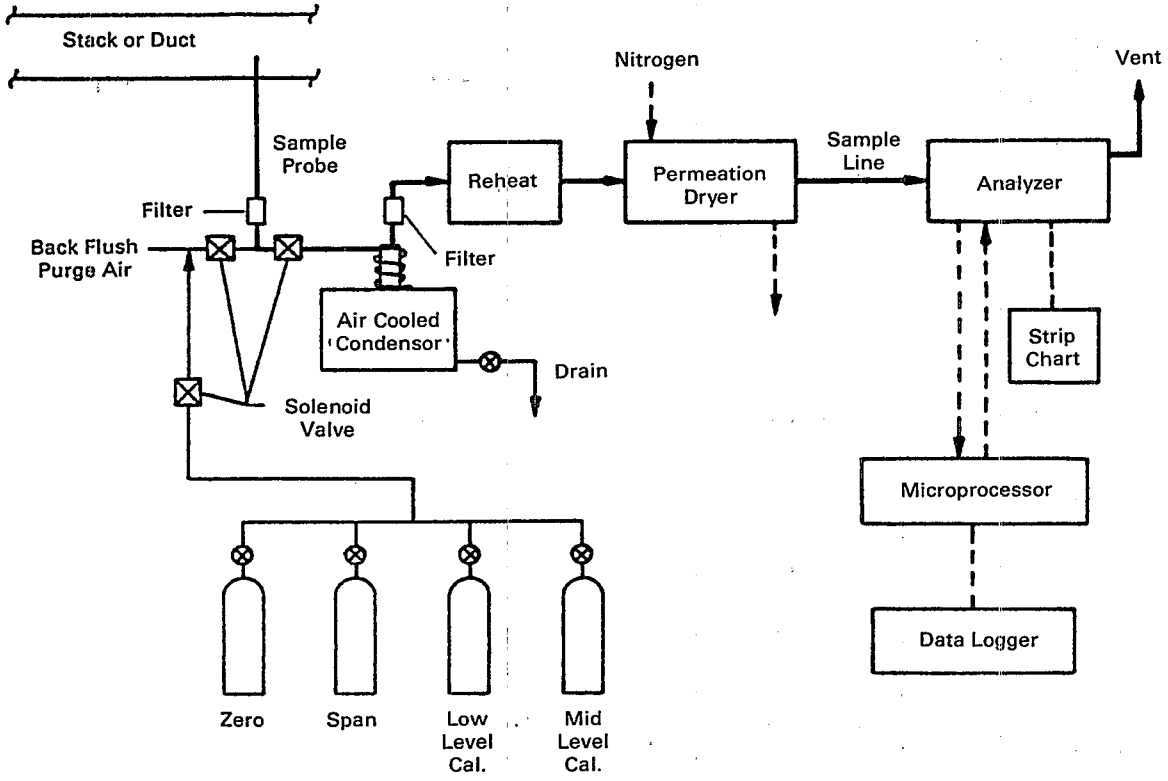

Figure 2. Example extractive system.

4. Establish a calibration procedure that assures accurate results and is easy to use.

5. Keep the system as simple as possible.

Performance Criteria and Evaluation

RCRA regulations do not specify performance criteria for monitoring systems. Recently, regulators have been referring to EPA's regulations under New Source Performance Standards (NSPS) for guidance on CO monitoring performance criteria. EPA's New Source Performance Standard (NSPS) regulations (40 CFR 60, Appendix A) include Reference Method 10 for determination of carbon monoxide. Although this method is intended specifically for compliance testing of Petroleum Catalytic Cracking Unit Catalyst Regenerators, Agency personnel often cite the method and refer to it in relation to CO monitoring of hazardous waste incinerator emissions. Table 2 summarizes the design and performance criteria established in Method 10. The criteria are a good starting point, but one should not be tied to them; this is further discussed in the following paragraphs.

Table 2. Criteria Established in EPA Method 10 for CO

• Luft type NDIR
• Minimum 20 ppm sensitivity
• 1,000 ppm range
• Zero drift—10% in 8 hr
• Span drift—10% in 8 hr
• Precision—± 2% of full scale
• Linearity—2% of full scale
• Rejection ratio—CO_2: 1,000 to 1 H_2O: 500 to 1

Performance Specification 4 for continuous monitoring of carbon monoxide emissions (40 CFR 60, Appendix B) was developed for evaluating CO monitors required under NSPS regulations. Table 3 summarizes the performance requirements. Performance Specification 4 involves conducting a zero/span drift test to evaluate performance and "certify" the monitor. Note that Performance Specification 4, as written, is designed only for the initial evaluation and "certification" of the monitor; it does not include provisions for continued evaluation of the monitoring system (e.g., daily calibration checks).

What performance criteria make sense for a CO monitoring system at a hazardous waste incinerator? First, performance criteria should be established for both a pretrial burn performance evaluation *and* for an ongoing evaluation during operation.

Table 3. Requirements of Performance Specification 4 for CO Monitoring[a]

24-hr zero/span drift	< 5% of span
Relative accuracy (Method 10 NDIR exempt)	< 10% of Reference Method

[a]40 CFR 60, Appendix B.

Items which require consideration prior to the test include:

a. Instrument range (span)
b. Initial calibration procedure
c. Calibration drift check procedure and frequency
d. Accuracy

Instrument Range. Instrument operating range is specified by the manufacturer. Typical ranges are 0 to 1%, 0 to 1,000 ppm, or 0 to 500 ppm. For a hazardous waste incinerator, a range of no more than 0 to 1,000 ppm or 0 to 500 ppm generally is desirable.

Instrument Calibration. The level at which calibration will be conducted, as well as the procedures used and the frequency, should be evaluated and established. It may be desirable to calibrate the instrument at a point less than full scale. Figure 3 is an example of the relationship between instrument span, calibration level, and normal operating level. Typically, calibration is conducted at a point somewhere between the normal operating level and the full scale span. For example, if a source normally operates at 50 ppm, and full scale span is 1000 ppm, calibration might be conducted at 200 ppm. During an initial evaluation, it is desirable to check the instrument calibration at more than one level. In the example above, an additional calibration check during initial evaluation at 50 ppm is desirable using multipoint calibration checks across the entire operating range of the instrument. The procedure used for calibration must be specified and should include as much of the entire monitoring system as possible (i.e., sample conditioning system, sample line, etc.). Sometimes it is not practical to include the entire sample transport system (i.e., the sample line from the stack) in the calibration. In such cases, the transport system must, as a minimum, be checked for leaks.

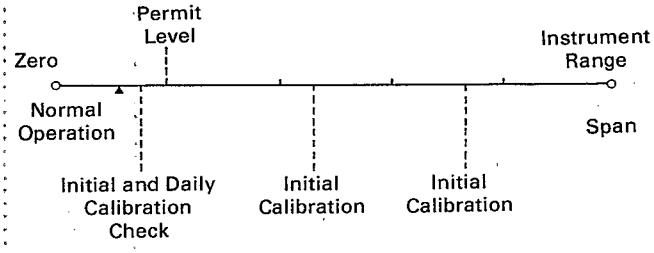

Figure 3. Instrument calibration.

Calibration Drift Check Procedure. How well the instrument will hold calibration over a period of time must be evaluated. The criteria of Performance Specification 4 are recommended, i.e., a 24-hr drift check. Calibration drift is checked at 24-hr intervals for 1 week. The 24-hr drift must not exceed 5% of instrument span. Note that a tighter drift requirement may be desirable in some cases. For example, for an instrument with full scale span of 1,000 ppm, the allowable drift (by Performance Specification 4) is 50 ppm. If the facility's emission level is normally 40 ppm, allowing a 50-ppm drift really is not desirable. A 20-ppm drift is more desirable and is reasonable since most manufacturers will specify a drift of ≦ 2% of full scale (2% of 1,000 ppm = 20 ppm). Also note that had the same facility installed a monitor having a full scale span of only 500 ppm, Performance Specification 4 would stipulate an allowable drift of only 25 ppm. It is obvious that simply specifying use of Performance Specification 4 criteria may not be equitable in all cases or even make sense. In fact, a more reasonable approach is to look at the particular situation and the instrument specifications to establish reasonable drift requirements and then establish drift requirements in terms of ppm rather than percent of full scale. The procedure used and the concentration level at which the calibration drift check is conducted should be stipulated.

Accuracy. It is desirable, but not necessary, to independently check monitor accuracy prior to the trial burn. For extractive monitoring systems, this may be done by entering an "audit gas" into the sampling system or by actually measuring the stack gas with an independent measurement system, i.e., another monitor. For an *in situ* system, an independent measurement of the stack gas generally is required if monitor accuracy is to be verified. Note that since no criteria exist for defining an acceptable accuracy, judgment must be exercised in determining if results are acceptable.

The pretest evaluation is necessary to assure the monitoring system is performing properly prior to the trial burn. Continual evaluation of the monitoring system performance is required to assure that monitor performance is acceptable on a continuous basis during normal operation. The primary means of evaluating performance is a daily zero drift and span drift calibration check. This check is conducted daily in the same manner as the pretest calibration drift checks. Criteria should be established for the amount of drift which is unacceptable, consequently requiring a calibration adjustment or instrument recalibration.

An independent performance audit of the system accuracy is another means of checking continued performance. For example, an annual audit using a cylinder gas that has been independently certified can be conducted to evaluate monitor performance.

Operation and Maintenance

Routine preventative maintenance of any monitoring system is important if the system is expected to operate in a reliable manner. Each system is different and therefore will require different maintenance. Nonetheless, a maintenance program should be developed for each monitoring system. The permit should stipulate that a written maintenance schedule be prepared and followed and that a maintenance record log be maintained. The manufacturer's specifications provide an excellent starting point for developing an operation and maintenance program.

Data Recording Frequency and Record Keeping

One cannot assume that because a continuous CO monitor is installed that the data recording system is adequate. The type of data recording system (i.e., 2-in. strip chart, 12-in. strip chart, or data logger) should be specified. The frequency of measurement (how often the analyzer measures the gas) and the frequency of recording the data (i.e., "continuously," every 10 sec, 3-min averages) also should be specified. Use of both a strip chart and data logger is desirable, but not necessary. The strip chart allows the operator to see what is happening on a real time basis and to evaluate trends. The strip chart should be located in the control room. The data logger allows a convenient method for summarizing and evaluating data over a longer period of time. For example, minimum and maximum values for each hour or each 24-hr period can be recorded and stored. The number of times an alarm has been activated can be tabulated. Daily calibration results can be conveniently recorded and compared to previous records for evaluating instrument drift.

Data Evaluation and Establishing Permit Conditions

The data obtained during a trial burn will be used to establish permit conditions for the allowable CO level in the stack gas during routine operation. When the permit limits are exceeded, the waste feed must be cut off.

Several factors related to evaluating data and establishing limits must be considered; these are briefly discussed in the following paragraphs. How does the permit writer handle brief "excursions" or "upsets" which result in brief but significant increases in CO? Should the permit allow a time delay before waste feed shutoff or is an immediate shutdown required? If CO excursions are noted during the trial burn (and the feed is not shut off), then the permit writer can base time delays allowed in the permit on the actual trial burn data. However, if no excursions were observed during the trial burn, a time delay for waste feed shutdown still makes sense. For any monitoring system there is a lag in the measurement of an event; consequently, it makes sense to take the response (lag) time into consideration before initiating a shutdown. For example, for a brief excursion lasting only 30 sec, by the time the event is monitored and the waste feed shut off, the event will likely be over. A shutdown and startup of the waste feed may actually result in more emissions than the event itself.

How does the permit writer handle a case where the emissions are very low (< 20 ppm) throughout the test and a very high DRE is obtained (> 99.9999). Is the limit set at not to exceed 19.5 ppm even though the stated (and demonstrated) monitor precision is ±20 ppm?

When the CO level varies widely (e.g., varies over a range of 50 to 100 ppm) during a trial burn but does not include obvious excursions (e.g., 300-ppm peak) is the standard set at the maximum level during the burn (e.g., 100 ppm) or some mean level (70 ppm for 2 min) or both.

Currently, there are two types of permit limits being written:

a. Single level standards
b. Double level standards

Single Level Limit. The simplest type of permit limitation is a single level standard, i.e., a single emission limit is set. This type emission limit would only be applicable to an incinerator for which the CO levels are very steady. The limit does not generally allow for excursions. The limit can take the following forms:

a. Not to exceed Y ppm (where Y = 70 ppm, for example). This standard does not allow for any time delay for instrument response time nor for brief excursions.

b. Not to exceed Y ppm (where Y = 70 ppm, for example) for greater than 30 sec. This limit allows a brief time delay prior to shutdown for response time lag and for very brief excursions.

c. Y ppm (where Y = 70 ppm, for example) for 5-min average. Use of a time averaged emission level allows the limit to be set at a lower level than the "not to exceed" limit. However, use of a time averaged standard can diminish the ability to quickly identify excursions, depending upon the time averaging period. The longer the averaging period, the more difficult identification of excursions becomes.

Dual Level Limit. A dual level limit incorporates all the options of a single level limit and allows additional flexibility in establishing permit conditions. This type of limit can be used where significant CO emissions excursions are noted during the trial burn; for example, when brief but distinct CO peaks are noted during charging of solids to a rotary kiln or fixed hearth incinerator. Two examples of this type of permit condition are:

Example 1:

- Level 1: Not to exceed 50 ppm for greater than 3 min
- Level 2: Never to exceed 1,000 ppm

Example 2:

- Level 1: 50 ppm for a 5-min average
- Level 2: Never to exceed 1,000 ppm

The advantage of this type of limit is that a time delay is provided for brief excursions before waste feed shutdown is initiated. However, a maximum limit also is provided to quickly identify major upset conditions. There are many other combinations of never to exceed values, limits with a time delay, and average limits that can be considered.

Proposed Guidance on Establishing CO Limits

As previously mentioned, USEPA currently is developing specific guidelines for the monitoring of CO from hazardous waste incinerators. This guidance is expected to be established in the spring/summer of 1987. Initial indications are that the guidance will include establishing dual level permit limits for a facility. Limits based on average CO values for specified time periods, i.e., time weighted rolling averages are being considered.

The guidance being considered is for the CO measured at the stack, normalized to a standard oxygen concentration of 7%. Use of the oxygen normalized CO value will adjust for changes in dilution air (air in-leakage) and combustion excess air rates. Use of this format if adopted as guidance would require that facilities also monitor oxygen and that real time integrators be installed to calculate rolling averages.

Construction and Retrofit Guidelines for Existing Incinerators

By

Joseph J. Santoleri
Four Nines, Inc.

Introduction

The proper and continuous operation of an incineration system for hazardous wastes has become a major responsibility of the Plant Engineer. Owners and operators of incinerators have had to submit completed applications for the Part "B" operating permit on existing incinerators by November, 1986. As part of the Part B permit, a Trial Burn Plan is needed. The Trial Burn Plan spells out the conditions under which the incinerator will be operated to determine the permit conditions to be established between the permitting agency and the operator. Many incinerators for which there has been application for the Part B permit have had interim status for at least 6 to 8 years, having received this in 1978. Now that the Trial Burn Plans have been submitted and the equipment needed to operate the unit permanently has to be installed and in operational condition prior to the Trial Burn, many organizations are taking a hard look at whether they have a unit capable of meeting these conditions. The permit and the Trial Burn have established the recording and monitoring procedures necessary to ensure that the incinerator operation is within approved parameters. It has been found through Mini-Burns that many incinerators do not meet the conditions necessary to be approved in the final Trial Burn. As a result, many installations are going through a retrofit program to bring the incinerator to the point where it has an excellent opportunity of passing the Trial Burn conditions.

To determine the potential for an incinerator to meet the Trial Burn conditions, Mini-Burns are recommended. These burns will provide the incinerator owner a better understanding of what his equipment can do in its present condition and what changes may be required to bring the system up to the performance necessary for the Trial Burn. Although this discussion focuses on the problems related to the pumpable liquid wastes burned in liquid injection units, the concepts developed can be applied to other incineration units such as rotary kilns, fluid bed combustors, two-stage combustors, and other incineration systems.

Materials Handling Problems

In transporting liquid wastes or slurries to the incinerator, the key elements are the storage facility, transfer and heat pumps, metering, control and shutoff valves, and the atomizers. Wastes vary from highly aqueous materials with organics and ash (typical of pharmaceutical and agricultural process wastes) to viscous tars such as toluene diisocynate with a viscosity of 4500 ssu at 300°F.

The transport system should be designed to prevent blockage in the lines due to waste shutoff to the incinerator, pump failure or inadvertent shutoff to the waste system. It is important that the following waste data be analyzed to determine whether the system as designed can properly transport and feed the waste into the incinerator, create no problems with refractory construction and eliminate problems in the waste heat recovery and air pollution control systems downstream. These waste data are:

1. Chemical composition
2. Heat of combustion
3. Physical data (if not liquid)
4. Viscosity
5. Corrosivity
6. Reactivity
7. Polymerization
8. Ash/Inerts content
9. Fusion temperature of ash
10. Combustion product analysis
11. Nitrogen composition

Design Details of the Incinerator

Incinerator systems should be reviewed and include but not be limited to the following:

Physical dimensions

Materials of construction

Feed device

Injection method

Auxiliary fuel system

Combustion air system

Quench system

Scrubber system

Controls, Monitors and Alarms

Knowing information about the waste, the flow rates of the waste, and the compositions as well as heating values, one can determine the ability for the system to reach these capacities. We have found systems that were designed for one set of conditions initially when the system was installed; however, the process plant changes created new waste streams that are now being handled by the incineration system. A closer review of the capacity of the system to handle these new wastes should be made. This will include the capacity and the composition of the waste regarding the air available which determines the overall capacity of the system and the downstream scrubber system, depending upon the concentration of the waste and what acid gases are generated. In some cases, the system has been modified for the type of solids injected into the incinerator. The physical data for the solids may affect the type of scrubber that has been installed.

To determine the capability of the system to meet the conditions for operating in the Trial Burn, a Mini-Burn or test program should be set up. The waste streams should be defined with the feed rates, compositions, heating values, water content and ash content; next, the operating temperatures of the various components of the system, such as the primary or kiln and the secondary chamber. In a liquid injection incinerator, this would be the primary chamber only. A review should be made of the air rates, and methods of determining the measurements of these rates. In case of the induced draft fan systems, this may be done only through stack discharge of the induced draft fan with a balance made with the air supply through the forced draft fans. Measurements can be made of all streams and tests should be conducted to determine these rates.

It is important that a sampling procedure be established to monitor the combustion efficiency and DRE of the selected POHCs. If ash is contained in the waste, the particulate emission should also be measured. If chlorinated hydrocarbons are injected into the system, a means should be developed for measuring the overall efficiency of the scrubber. In other words, the HCl entering and leaving the scrubber should be sampled so that the efficiency of the scrubber can be determined.

Prior to formal Mini-Burn, observation of the unit should be made while the unit is in normal operating conditions. It is sometimes feasible to make interim modifications prior to the Mini-Burn based on the preliminary observations. This is often done to provide better feed conditions, better atomization if liquid waste, better control on draft, improvement to pH control system, also improvements to the venturi pressure drop control, etc. Normally, these modifications are minor in nature and should not require much of a design effort nor an installation effort. Once the test program is set up and the information is obtained as a result of the testing, the real involvement in retrofit design begins; however, it is important to know that the Mini-Burn should basically cover the variety of wastes to be handled in the Trial Burn. Sufficient data should be taken on the rates of the waste streams, the composition of the waste streams, and the resulting emissions from the stack, scrubber discharge and ash discharge.

The advantages of the Mini-Burn are that it provides a complete run-through of all the systems involved in operating the incinerator. The problems that have occurred in these Mini-Burn tests are covered in more detail in the papers enclosed with the handouts at the meeting. The paper, "Trouble Shooting and Upgrading for Incineration Systems," covers several types of incinerators and the problems related to the operation of those units. A second paper entitled, "Design and Operating Problems of Hazardous Waste Incinerator," also goes into the many areas that should be looked at during the Mini-Burn. Once these problems have been found, the next phase of the project involves interim modifications with subsequent testing. These may again be minor modifications without major revisions or design effort. Tests should still be conducted to prove the adequacy of these changes. Based on the results of these Mini-Burns, a final design is started. In most cases this begins with a conceptual design and budget costs covering the changes needed and the importance of these changes. These are reviewed with the owner of the incinerator and his engineering staff; in some cases, some of this work can be handled directly by in-house engineering and fabrication departments. In other cases, the entire project is assigned to the consultant with detailed design and purchasimg assistance provided. This will include specifications for all equipment that has to be purchased, selection of vendors, review of bids, and assistance in placing the purchase orders for these items.

The next phase of the retrofit includes the overall program management which includes the following:

Purchasing

Fabrication and Inspection

Shutdown and Installation

Pretest Checks

Again, this phase is one that can be handled by internal personnel of the incinerator owner with assistance from the consultant, or it can be done completely by an outside consulting and engineering firm. In any case, it is not much different than programs involved in the initial purchase and installation of the equipment; however,

since it does include a retrofit, it does include much more careful investigation of the existing equipment since modifications may have been made from the original drawings to the final installation. Changes to the instrumentation and hardware from the original installation may have been made; therefore, these must be carefully checked to be sure that whatever design changes are incorporated will fit into the final unit.

Scheduling of the shutdown must be carefully planned to ensure that no problems will occur with storage or buildup of the waste materials during the time the retrofit is completed. This requires liaison between the plant operations, the incinerator operations, the vendors who are supplying the equipment, and the installation contractors. Since it is a high temperature furnace, the other areas that must be carefully observed are the cool-down needed for the refractory linings and the complete purging of all acid gases and ash-containing substances throughout the entire incinerator system. This will include the incinerator refractories and the scrubber system to purge out any build-up of salts or any other ash-containing materials. Shutdown will allow inspection of the entire system including the piping, valves, nozzles, refractories, pumps, operating linkages on valve arms, and damper controls. It also permits inspection and maintenance of all instrumentation including the temperature, gas analysis and pH controls.

After installation, tests should be scheduled prior to the first full-scale Mini-Burn test. Pretest should be made of all the new equipment that has been installed. This includes all rotating machinery, motor drives, belt drives, etc. All automatically controlled valves should he checked for the stroke of the valve through its full range. All instrumentation should be fine tuned by instrumentation mechanics. If new refractory has been installed, this should be placed through a proper curing cycle and this scheduled with the incinerator operations department. Once the pretests have been completed, the unit should be brought on-line utilizing fossil fuels such as natural gas, No. 2 oil, to allow the unit to go through its operating temperature range and total flow range. This will also permit complete fine tuning of all instrumentation and controls.

Next, the waste burning test should be scheduled. This will be a duplication of the Mini-Burn test to ensure that all the modifications that have been designed into the retrofit will meet the conditions necessary for the final Trial Burn. Scheduling should be basically the same as the final Trial Burn except it may not be necessary to go through the entire range of wastes or cases as one would in the final Trial Burn. The main purpose of this is to ensure that modifications will meet the conditions for which they were designed.

Upon completing the final Mini-Burn tests and reviewing the process and sampling data, determination of the readiness of the incineration system for the final Trial Burn should be made. If all the conditions of DRE, HCl removal and particulate levels in the stack emissions have been met, the unit is now ready for the final Trial Burn. Prior to this all modifications which affect the Trial Burn plan should he included in the Trial Burn plan. These should then be submitted to the inspection agency. Meetings will then be held to review the conditions for the Trial Burn and hopefully at this point all NODs will have been eliminated. Following these meetings the final Trial Burn schedule will be set up and arranged.

In the past two to three years, many systems have undergone the procedures outlined above in bringing a unit up to the conditions necessary to meet and pass the Trial Burn. I have tried to outline here the steps that are required. There are variations depending on the installation and the type of equipment but basically the procedures will follow the outlines as indicated above.

Case Studies for Trial Burns

By

Joseph J. Santoleri
Four Nines, Inc.

Background

A questionnaire was developed to generate information that could be used in this portion of the program. A total of 36 questions were asked regarding all phases of the Trial Burn Plan. This included the information as prepared in the Trial Burn Plan including any comments or reviews by the inspection agency, whether it be the State or the EPA; the follow-up by the incinerator owner with the inspection agency, and the most important section, that of the Trial Burn itself. These questionnaires were forwarded to four locations with different types of incinerators. The one that responded with the most detailed information was from a rotary kiln chemical process plant. This facility was the Eastman Kodak Company in Rochester, New York. Kodak Park is the central location for Eastman Kodak Company for producing film. As a result, a fairly large chemical complex is located at this facility. Due to the chemical processes involved, many wastes are generated in the forms of solids, sludges and liquids.

The present incineration system handles these particular wastes on a day-to-day operation. The schematic shows the entire incineration plant which involves a rotary kiln followed by an afterburner: then a quench chamber followed by a venturi scrubber, packed tower, two induced draft fans in series, and finally the stack, 250 ft. high. The wastes are brought into the plant in tank trucks and delivered to storage tanks. These tanks are designed with internal mixers so that a homogeneous mixture can be maintained in the tank. The liquids are then pumped out and fed directly to the kiln burners or into the auxiliary burner firing the afterburner chamber. Many locations exist for feeding liquids both at the front end of the kiln or in the auxiliary burner firing at the base of the afterburner chamber. This burner provides the heat necessary to maintain the afterburner temperature. The sludges are brought in tote boxes, again pumped by diaphragm pumps over to the storage tank where they are mixed and fed into the sludge burners located in the front of the kiln. Any wastes that contain inorganic materials are also fed into the kiln. The storage and handling of these wastes are such to prevent any ash-containing waste from being fed directly into the auxiliary burner. However, high aqueous materials containing organics and inert ash are fed into a series of nozzles located on the periphery of the auxiliary burner in the afterburner. Combustion air is supplied through forced draft fans providing air to the burners at the front end of the kiln and also through forced draft fans to the auxiliary burner. The induced draft fans at the exit of the scrubbers are used to induce air in through the front end of the kiln through an automatically controlled damper. The total volume of gases traveling through the kiln are generated by the forced draft fans feeding the burners at the front end of the kiln as well as the air through the inlet duct of the kiln. The bulk of the gas flow through the kiln or through the entire incinerator system is determined by the total stack gas flow. At Kodak the amperage of the motors used to drive the induced draft fans was used as a means of measuring the total volume flow through the system. This provides a measurement of the volume of gases in the afterburner chamber which permits calculation of the residence time in this chamber. The afterburner is constructed as two vertical chambers with the gases traveling vertically up after leaving the kiln and making a 180° turn through a vertical down chamber. The auxiliary burner is firing at the bottom of the first chamber into the gases as they exit the kiln. This provides good contact of these gases with the flame surface and ensures that all gases leaving the kiln pass through the flame front. The high intensity of this burner ensures that all gases are brought up to the secondary chamber temperature and maintained at that temperature throughout the full length of the two vertical chambers. After the gases leave the second vertical down chamber, they enter the quench tower. Water is sprayed in through the top of the tower contacting the gases in a counterflow arrangement. This permits the gases to be completely saturated prior to entering the venturi scrubber. This ensures high efficiency on the scrubber by having the gases fully saturated prior to entering the throat of the scrubber. The excess water sprayed into the quench tower drops to the bottom of the vertical quench chamber and is recycled into the spray nozzles. The venturi scrubber is used to scrub the ash generated in the incineration process which includes the ash carryover from the kiln into the secondary chamber and any ash generated by the aqueous wastes introduced into the secondary chamber. After these particulates are scrubbed through the high energy venturi, the gases then travel through a packed tower absorber where they are contacted by a caustic solution to scrub out the HCl gases generated from the chlorinated wastes. At this point the gas temperature is approximately 150° F. After passing through the packed tower, the gases enter the induced draft fans and are then forced up through the stack. The system includes two induced draft fans to provide a total pressure drop across the venturi and packed towers of

approximately 78". This level of pressure drop is required due to the particulates generated in the incinerator. With only a single fan operating, the pressure drop provided is in the range of 45-50". When solids are not burned and most of the waste being burned is solvents containing very little ash, the system can be operated with only a single fan, thereby reducing horsepower. In order to assure complete scrubbing of the HCl, caustic is introduced into the pH control system. As the gases pass through the venturi and eventually into the packed tower, they are contacted by recycled liquids from the pH control. The pH is maintained at a level of 6-7. This insures that the HCl is scrubbed out and the liquid used in recycle is neutral or slightly above neutral. Due to the reaction time of the pH control system and the spikes that can occur due to the introduction of high chloride wastes, the pH control system will vary and allow the recycled liquid to go to the acid side. The number of times the pH will spike down determines how well the system can handle the chloride load. Minimum pH allowable for alarm and shutdown is 1.5.

The total heat capacity generated in this incineraton system is approximately 120 MM Btu/hr. Note that the system does not contain a waste heat boiler. At the time the system was installed, waste heat recovery from this type of waste burning was not designed with waste heat recovery in mind. The main purpose of the system was a means of waste disposal by incineration. However, with the quantity of heat that is generated, consideration may be given in the future to add waste heat recovery. This should generate about 80,000-90,000 lb/hr. of steam. Information regarding the schedule of the Trial Burns, the modes in which the Trial Burns were planned, the schedule of the daily testing, and the results of the Trial Burn which includes the DREs, the particulate removal and the HCl removal are all shown in the handouts provided. One thing that should be particularly pointed out for this case study is the Mini-Burns that were conducted by Kodak to ensure that all systems were optimized. This included all the existing control functions as well as all the instrumentation, monitors and safeties. It is recommended that any system go through a Mini-Burn before a final Trial Burn is scheduled. Kodak went through a period of 3-4 years of various tests. A concentrated test period took place over about 4 months proper to the final Trial Burn. This permitted complete debugging of all the problems that would have occurred during the Trial Burn which may have caused a shutdown and increased the expense of the Trial Burn operations. Some items that were changed were the flow meters for measuring liquid flows, nozzles in the burners and aqueous waste injection, refractory design, CO and O_2 monitors; also improvement in the sampling trains for the CO and O_2 monitors to prevent the nuisance shutdowns that had been occurring.

One of the most important areas reported by Kodak personnel was the good communications between Kodak and the regulatory agency. In the case of Kodak, it was necessary to deal with the regional U.S. Environmental Protection Agency (EPA) office as well as the New York State Department of Environmental Quality (DEQ). Before the final Trial Burn was submitted, discussions were held and various areas of the Trial Burn Plan were revised before the Final Plan was submitted. A good line of communications between the agency and the incinerator operating team is necessary. It is important that the permitting agency know exactly what your plans are; they can make recommendations on problems that occurred at other facilities in your area or pass on information regarding Trial Burn Plans in other regions that they are aware of. In the case of Kodak, the Trial Burn Plan with specifics including permit limits and rationale for establishing those limits was established early in the game. The EPA came back with recommendations that were reviewed and discussed with Kodak.

One of the conditions that was established for this Trial Burn was a worst case scenario so that these conditions would all be tested during a Trial Burn. As you will note from the schedule, it was not a single day of testing; it was a series of days.

It was decided that the test basis for the Trial Burn include the worst case scenarios. This included the maximum heat release rate, maximum combustion gas volume, minimum kiln incineration temperature, minimum afterburner incineration temperature, minimum oxygen level, maximum ash load, maximum chloride level, minimum venturi pressure drop, minimum pH level, and maximum amperage on the I.D. fan. Some of these are interrelated but these were the goals for the Trial Burn testing.

One of the major items that had to be considered in the Trial Burn Plan was the selection of POHC. Dayton Research Institute laboratory assisted in determining POHCs selection. Various methods of ranking POHCs are available. At present, heat of combustion is a method of ranking. The compounds having the lowest heat of combustion, which are considered the most difficult to burn, are those that are normally selected as a POHC. This can be considered as a surrogate or as a compound contained in the actual waste generated at the facility. A second means of ranking is the auto-ignition temperature. This has been discussed at great length concerning whether it should be used as the means of determining POHCs based on the difficulty of ignition and combustion. The third column which is headed, Flameless Oxidation, is that temperature at which the vapors generated achieve a 99.99% destruction efficiency with a 2-second residence time. This assumes that a portion of the material does not go directly through a flame front. The ability of the incinerator to reach the 99.99% DRE of the material in this situation determines the difficulty of oxidation. Note that acetonitrile ranks No. 1 with a temperature of 951°C necessary to reach the DRE. In the ranking under Heat of Combustion this is ranked No. 10. Tetrachloromethane which ranks No. 1 in both heat of combustion and auto-ignition temperature is ranked No. 3 in the flameless oxidation method of ranking. As a result, both acetonitrile and tetrachloromethane were selected as the POHCs for the Trial Burn.

In the Test Schedule five separate operating modes were selected and the dates of tests were one week apart. The reason was the quantity of surrogate compounds that

had to be put together for each daily run. Kodak allowed a week between tests to collect enough materials. They had the advantage that all of the stack emission testing as well as the ash and waste analysis testing were done by Kodak's in-house testing group. Therefore, this eliminated the problem in having to bring in an outside sampling firm to the site on five separate weeks.

In the Daily Test Plan four tests were set up for the daily schedule. This was done to insure that if one of the tests failed due to an outside influence, that is, a process problem, equipment problem, etc., sufficient data would be available for DRE, HCl and particulate calculations. By allowing time for four separate runs each day, they could eliminate one due to a failure problem.

One item which could have been considered another sample point was the make-up water or the fresh water inlet to the quench chamber. Since chlorides are balanced throughout the system, the analysis of this water for chlorides would have added another means of a material balance to the system. In some areas where the chloride content of water is high, this would add an error into the incoming stream which may not be considered.

Note that the stack gases were sampled at two locations, one directly beyond the silencer in the Location 7. This was used for the monitors measuring oxygen and carbon dioxide with portable monitors. CO is also analyzed at this location using a continuous recorder. At Location 8 the flow rate was measured as needed by a stack emission test as well as the Orsat for measuring moisture. Method 5 tests were also run to measure particulates and HCl levels. It is recommended that a schematic such as this be included with any Trial Burn Plan. This ensures not only that the sampling contractor understands what is required with regard to the sampling program, both for wastes, ash: scrubber discharge and stack emissions, but also ensures that the process data are obtained for all flow measurements, temperature measurements, pressure measurements, etc. It serves as a good check tool for the consultant supervising the Trial Burn. It also provides the inspection agency with information so that they will have it available during the Trial Burn proper.

The Eastman Kodak report includes the results of DRE, HCl removal and particulates. The final permit limit summaries include the limits of temperature for both the kiln and secondary chamber with the waste feed cut-off points necessary based on the temperature drops in either chamber. This waste feed cut-off establishes when the liquid waste is cut and when the solid wastes are cut. The permit limit also sets a maximum amperage on the combustion gas flow based on the horsepower level of the I.D. fan. The carbon monoxide level which had initially been established with a permit limit of 120 ppm was later changed to a level of 90 ppm where the average condition of 128 ppm indicated a DRE level of 99.98995% for acetonitrile. It was decided between the Eastman Kodak people and the New York DEQ that 90 ppm be established as the limit for carbon monoxide. Note that two stages of hazardous waste feed shutdown should occur based on the rolling 1 hr average limit of 90 ppm. If the rolling average CO exceeds 90 ppm at any time, the containerized solid waste system shall shut down automatically and remain shut down until the average rolling CO has dropped below 90 ppm for 15 minutes. All hazardous wastes should automatically shut down if the rolling average CO exceeds 90 ppm for 15 minutes. This includes not only the solid wastes but also the liquid wastes. However, once the rolling hour CO has dropped below 90 ppm for at least 15 minutes, the liquid hazardous waste feed may then be resumed. Solid waste may then be resumed 15 minutes later providing the CO level remains below 90 ppm. An instantaneous level of 1000 ppm was established as a condition which would automatically prevent feeding any containerized solid waste.

With regard to the particulate load to the scrubber, a maximum ash content in the liquid waste was established at 3%. The solid waste loading limit was variable depending on the type of solid waste. In the event of a finely divided inorganic solids such as diatomaceous earth and sodium chloride salt, no more than 20 packs per hour could be fed to the incinerator. The normal rate of containerized solid waste allowed has been 45 packs per hour; however, with the finely divided inorganic solids, a high particulate loading can be generated since the ash can be airborne.

Summary

The above case study covers in detail the results of the installation at the Eastman Kodak Plant in Rochester, NY. It points out the importance of good communications between the incinerator operator and the regulatory agency. It also points out the importance of a concentrated Mini-Burn schedule to ensure that all problems that can occur during a Trial Burn can be minimized by proper design of the Trial Burn and also proper selection, maintenance and calibration of the equipment. The total elapsed time for the Part "B" permit approval was about 29 months. After the Trial Burn was completed, about 3 months was needed to get a report from the analytical firm on all of the analyses taken during the Trial Burn. This was submitted to the agency and about 14 months later the final permit for the Part "B" was issued. Delays occurred due to the review of the Trial Burn reports and modifications of the permit conditions by the permitting agency. This, of course, required negotiations between the two parties to come to a final decision. One of the problems that did occur was the change of permit writers during this overall submittal period.

The major result of the entire review of this case study points out the need for communications right from the start in the planning stages with the incinerator operator and the agency. Also important is that communications continue throughout the program between the supervisor of the Trial Burn, the operating department of the plant, the maintenance and instrumentation sections of the plant, as well as the sampling personnel. Good coordination is required by all parties and again, continued communications with the permitting agency.

Permit Writer's Guide to Test Burn Data

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Abstract

The PERMIT WRITER'S GUIDE TO TEST BURN DATA is a new guidance document prepared by the Environmental Protection Agency's (EPA) Center for Environmental Research Information for use in the permitting and testing of hazardous waste incinerators regulated under the Resource Conservation and Recovery Act (RCRA). Results from hazardous waste test burns conducted in the U.S. at 23 full-scale stationary incinerators are summarized.[1-3] In addition to the incinerator test burn data, the book also contains results of test burns at 11 U.S. lime, cement, and aggregate kilns, and 9 industrial boilers.[4-17]

This is the first time that a data book containing results from a wide variety of combustion tests has been assembled. The document is a beneficial source of information for those involved in the planning, execution, and evaluation of hazardous waste trial/test burns, and should be used in conjunction with other EPA guidance documents on hazardous waste incineration.

Introduction

The Resource Conservation and Recovery Act (RCRA) requires that hazardous waste incinerators adequately destroy hazardous organic compounds while maintaining acceptable levels of particulate and chloride (HCl) emissions. Owners and operators of these incinerators must demonstrate the acceptable performance of the facility by means of a trial burn. Consequently, industry and control agency personnel have become involved in planning for, conducting, and interpreting the results from trial burns as an integral part of the RCRA permitting process.

In an effort to assist the RCRA permitting process, the EPA has prepared this test burn data book as a reference document for use in reviewing trial burn plans for hazardous waste incinerators and other thermal treatment devices that are now or may soon be regulated under RCRA. The book summarizes the results from hazardous waste test burns conducted at 23 full-scale stationary incinerators in the United States. Nine of these test burns were designed and conducted by the EPA and its contractors as part of EPA's Regulatory Impact Analysis of the RCRA incinerator regulations. The other 14 were conducted separately and individually by private industrial concerns and their contractors as part of their Part B application requirements for obtaining full operating permits under RCRA.

In addition to the incinerator data, the book also contains data from hazardous waste test burns at 11 lime, cement, and aggregate kilns and 9 industrial boilers in the United States. The EPA conducted these tests as part of an overall research program aimed at determining the efficiency of these thermal units for cofiring (and thereby destroying) hazardous wastes as fuel supplements or replacements. The practice of substituting hazardous wastes for fossil fuels in kilns and boilers is currently exempt from RCRA regulation, but this situation may change as more is learned about the overall effect of typical kiln and boiler operating conditions on various waste-oriented performance parameters, such as waste destruction and removal efficiencies, chloride and particulate emissions, and the formation of unwanted byproducts of combustion.

Basic data derived from each completed test burn involving the burning of hazardous wastes are presented on summary forms similar to that shown in Figure 1. The forms include information on the type of thermal unit tested, composition of the waste feed, operating conditions during each run, monitoring methods, and emission results. Baseline tests in which only auxiliary fuels or nonhazardous wastes were burned are not reported. Also, test runs which were aborted due to operational or sampling problems are not reported.

Summary and Analysis of Incinerator Performance Data

Analysis of available test data from 23 separate incinerators located throughout the United States yielded data on 57 different POHCs tested during 126 different runs for a total of 534 POHC/test run combinations. A complete tabulation of key data from these 534 POHC/test runs can be found in Table 1. This table can be used to quickly identify POHC DRE results, POHC concentrations tested, temperatures tested, and questionable test data. When used in combination with other tables presented in the report, this listing can be useful in studying performance relative to various types

Incinerator Trial Burn Summary

Date of Trial Burn: _____

Run No.: _____

Incinerator Information:
Type of unit: _____
Capacity: _____
Pollution control system: _____
_____
Waste feed system: _____
_____
Residence time: _____

Commercial: ☐ Private/industrial: ☐

Trial Burn Conditions:
Waste feed data:
Type of waste(s) burned: _____
_____
_____
Length of burn: _____
Total amount of waste burned: _____
Waste feed rate: _____
POHC's selected and concentration in waste feed:

Name	Concentration

Btu content: _____ Chlorine content: _____
Ash content: _____ Moisture content: _____
Operating Conditions:
Temperature: Range _____ Average _____
Auxiliary fuel used: _____
_____
_____
Excess air: _____
Other: _____
_____

Monitoring Methods:
POHC's: _____
Cl: _____
Particulate: _____
Other: _____
_____
_____

Emission and DRE Results:
POHC's: _____
_____
_____
_____
_____
Cl: _____
Particulate: _____
THC: _____
CO: _____
Other: _____
PIC's: _____
_____
_____

Reference(s):
_____
_____

Comments: _____
_____
_____

Figure 1. Example data summary form.

of incinerators, various types of wastes, or controlled/uncontrolled conditions.

DREs for all of the incinerators tested were generally above 99.99 percent. Since the operating conditions monitored during the majority of the EPA tests were those selected by the plants as their normal conditions, it can be concluded that operating incinerators will generally obtain an overall performance level of 99.99 percent DRE or better.

Although all of the sites reported DRE successes, nine also reported periodic DRE failures. Though almost all POHCs were tested successfully (i.e., greater than or equal to 99.99 percent DRE) in one or more tests, more than one-third of the POHCs also had some unsuccessful tests (less than 99.99 percent DRE). The principal reasons believed responsible for these DRE failures are low POHC concentrations in the waste feed (i.e., <1000 ppm) and detection limitations inherent in the sampling and analysis methods. Such limitations often precluded the mathematical calculation and demonstration of 4-9's DRE, even though in reality such a level of destruction and removal may have been achieved. Low temperature also may have been a significant factor in some DRE failures. Overall, the data show that about 80 percent of the failures occurred when the POHC concentration in the waste feed was less than 0.1 percent (less than 1000 ppm) or the temperature was less than 2000°F.

Another factor identified as having negative impact on DRE involves choosing as POHCs those compounds that are also likely to be present as PICs in the stack gases. Several compounds have been previously identified as PICs; examples include chloromethanes, toluene, benzene, chlorobenzenes, and napthalene. The formation of these compounds during the incineration process would tend to increase their concentration in the stack gas, resulting in apparently lower DREs. In fact, many of the failures noted in Table 1 occurred when these types of compounds were chosen as POHCs.

Eight of the EPA tests and at least one of the trial burn tests investigated POHC levels in scrubber water and ash; the results show that POHC levels in these media are generally very low or nondetectable. These data suggest that the majority of POHCs are destroyed rather than merely transferred to another media in the incineration process.

Some Appendix VIII compounds detected in the stack (primarily trihalomethanes) appear to be stripped from the scrubber water by the hot stack gas. In the EPA tests, trihalomethanes detected in the scrubber inlet waters frequently were not detected in the effluent waters. Often, compounds of this type are used in scrubber waters to control microbial growth. When such compounds are chosen as POHCs, the result can be lower measured/calculated DREs even though the destruction mechanisms may not have been affected. Recent guidance from EPA-HQ states that all POHCs in the exhaust gases, including any POHCs that may be stripped from the scrubber, should be included in DRE calculations.[17]

Table 1. Summary Tabulation of Incinerator Test Results by POHC

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h	TSP, gr/dscf[b]	TEST No.	SPONSOR
McDONNELL DGLS	1,1,1 trichloroethane	71	99.99999	1800	0.8	0.032	2	Private
McDONNELL DGLS	1,1,1 trichloroethane	70	99.99999	1800	0.74	0.032	4	Private
McDONNELL DGLS	1,1,1 trichloroethane	62	99.99999	1800	1.64	0.044	3	Private
McDONNELL DGLS	1,1,1 trichloroethane	59	99.99999	1800	1.67	0.047	1	Private
STAUFFER CHEMICAL	1,1,1 trichloroethane	0.88	99.99998	1830	99.9	0.001	7	Private
STAUFFER CHEMICAL	1,1,1 trichloroethane	0.87	99.99998	1830	99.9	0.002	6	Private
STAUFFER CHEMICAL	1,1,1 trichloroethane	0.82	99.99998	1830	99.9	0.0009	4	Private
STAUFFER CHEMICAL	1,1,1 trichloroethane	0.83	99.99998	1830	99.9	0.003	5	Private
ROSS INCINERATION	1,1,1 trichloroethane	2.55	99.99952	2110	0.1	0.061	1	EPA
ROSS INCINERATION	1,1,1 trichloroethane	0.91	99.999	2090	0.3	0.077	2	EPA
ROSS INCINERATION	1,1,1 trichloroethane	0.58	99.999	2040	0.3	0.061	3	EPA
DOW CHEMICAL	1,1,1 trichloroethane		99.998	1810	99.9		10212-2	Private
DOW CHEMICAL	1,1,1 trichloroethane		99.996	1820	99.9		10212-1	Private
TWI	1,1,1 trichloroethane[g]	0.00792	99.966	2080	0.3	0.075	1	EPA
DUPONT-LA	1,1,1 trichloroethane[g]	0.001	99.932	2640	0.5	0.015	1	EPA
TWI	1,1,1 trichloroethane[g,k]	0.016	99.88	2230	h	h	6	EPA
TWI	1,1,1 trichloroethane[g,k]	0.0123	99.87	2140	h	h	8B	EPA
TWI	1,1,1 trichloroethane[g]	0.0105	99.86	2070	0.6	0.048	3	EPA
TWI	1,1,1 trichloroethane[g,k]	0.0087	99.84	2050	h	h	7	EPA
TWI	1,1,1 trichloroethane[g]	0.0051	99.82	1810	0.2	0.044	4	EPA
TWI	1,1,1 trichloroethane[g]	0.011	99.81	2030	0.4	0.127	2	EPA
TWI	1,1,1 trichloroethane[g,k]	0.0162	99.47	2120	h	h	8A	EPA
ROSS INCINERATION	1,1,2 trichloroethane	0.038	99.99999	2040	0.3	0.061	3	EPA
ROSS INCINERATION	1,1,2 trichloroethane	0.035	99.99999	2110	0.1	0.061	1	EPA
ROSS INCINERATION	1,1,2 trichloroethane	0.028	99.99999	2090	0.3	0.077	2	EPA
3M	1,1,2 trichloroethane	1.631	99.999	1890	0.8	0.08	10	Private
3M	1,1,2 trichloroethane	1.566	99.999	1985	0.2	0.091	4	Private
3M	1,1,2 trichloroethane	1.304	99.999	1905	0.3	0.047	6	Private
3M	1,1,2 trichloroethane	1.066	99.999	1885	0.4	0.048	7	Private
3M	1,1,2 trichloroethane	0.937	99.999	1915	0.5	0.047	5	Private
3M	1,1,2 trichloroethane	1.771	99.998	1930	1.2	0.154	8	Private
3M	1,1,2 trichloroethane	1.3	99.998	1925	0.7	0.078	9	Private
3M	1,1,2 trichloroethane	1.225	99.998	2030	0.44	0.0848	3	Private
3M	1,1,2 trichloroethane	0.548	99.994	1985	0.9	0.0623	1	Private
3M	1,1,2 trichloroethane	1.239	99.99	1950	0.48	0.112	2	Private
UNION CARBIDE	1,2 dichlorobenzene	2.1	99.99994	1600	98.9	0.066	7	Private
UNION CARBIDE	1,2 dichlorobenzene	1.6	99.99992	1800	98.2	0.075	6	Private
UNION CARBIDE	1,2 dichlorobenzene	1.7	99.9999	1600	98.6	0.055	11	Private
UNION CARBIDE	1,2 dichlorobenzene	1.5	99.9999	1600	98.1	0.073	2	Private
UNION CARBIDE	1,2 dichlorobenzene	1.4	99.9999	1800	98.4	0.064	12	Private
UNION CARBIDE	1,2 dichlorobenzene	1.4	99.99986	1800	97.9	0.07	3	Private
UNION CARBIDE	1,2 dichlorobenzene	2.2	99.99985	1600	98.9	0.048	8	Private
UNION CARBIDE	1,2 dichlorobenzene	2.1	99.99985	1600	98.5	0.057	9	Private
UNION CARBIDE	1,2 dichlorobenzene	1.3	99.99957	1800	98.3	0.061	5	Private
UNION CARBIDE	1,2 dichlorobenzene	1.4	99.99933	1800	98.2	0.071	4	Private
UNION CARBIDE	1,2 dichlorobenzene	5	99.99923	1600	98.2	0.094	1	Private
UNION CARBIDE	1,2 dichlorobenzene	1.2	99.99921	1800	98.5	0.056	10	Private
UPJOHN	1,2,4 trichlorobenzene	0.027	99.65	2040	0.9	0.094	2	EPA
UPJOHN	1,2,4 trichlorobenzene	0.039	99.75	2040	1.7	0.013	4	EPA
UPJOHN	1,2,4 Trichlorobenzene	0.029	98.6	2040	1.2	0.08	3	EPA
ROSS INCINERATION	2,4 dimethylphenol	0.071	99.9994	2040	0.3	0.061	3	EPA
ROSS INCINERATION	2,4 dimethylphenol	0.02	99.9992	2110	0.1	0.061	1	EPA
ROSS INCINERATION	2,4 dimethylphenol	0.02	99.999	2090	0.3	0.077	2	EPA
AMERICAN CYANAMID	aniline[c,e]	60	99.99999	1198	0.007	0.069	3	EPA
AMERICAN CYANAMID	aniline[c,e]	53	99.99999	1198	0.007	0.175	5	EPA
AMERICAN CYANAMID	aniline[c,e]	55	99.99999	1240	0.004	0.075	2	EPA
AMERICAN CYANAMID	aniline[c,e]	0.8	99.9997	1254	0.007	0.007	4	EPA
UPJOHN	aniline[c]	c	99.9988	2040	1.2	0.08	3	EPA
ROSS INCINERATION	aniline	0.026	99.998	2110	0.1	0.061	1	EPA
ROSS INCINERATION	aniline	0.026	99.998	2040	0.3	0.061	3	EPA
ROSS INCINERATION	aniline	0.021	99.998	2090	0.3	0.077	2	EPA
UPJOHN	aniline[c]	c	99.9988	2040	1.2	0.08	3	EPA
UPJOHN	aniline[c]	c	99.981	2040	1.7	0.013	4	EPA
STAUFFER CHEMICAL	benzene	4.68	100	1830	99.9	0.003	5	Private
STAUFFER CHEMICAL	benzene	4.53	100	1830	99.9	0.002	6	Private
STAUFFER CHEMICAL	benzene	4.47	100	1830	99.9	0.001	7	Private
STAUFFER CHEMICAL	benzene	4.65	99.99999	1830	99.9	0.0009	4	Private

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
TWI	benzene[k]	2.91	99.99979	2140	h	h	8B	EPA
TWI	benzene[k]	3.24	99.99952	2120	h	h	8A	EPA
TWI	benzene	1.52	99.9983	2080	0.3	0.075	1	EPA
TWI	benzene[k]	2.54	99.995	2050	h	h	7	EPA
TWI	benzene[k]	2.52	99.99	2230	h	h	6	EPA
TWI	benzene	1.18	99.989	2030	0.4	0.127	2	EPA
TWI	benzene	0.889	99.988	1810	0.2	0.044	4	EPA
MITCHELL SYSTEMS	benzene[g]	0.0116	99.986	2000	4.9	0.313	2	EPA
TWI	benzene	1.43	99.984	2070	0.6	0.048	3	EPA
MITCHELL SYSTEMS	benzene[g]	0.0067	99.82	2050	f	f	3	EPA
DUPONT-LA	benzyl chloride	0.233	99.9996	2640	0.6	0.004	2	EPA
DUPONT-LA	benzyl chloride	0.211	99.9996	2640	0.5	0.015	1	EPA
DUPONT-LA	benzyl chloride	0.219	99.9994	2640	0.9	0.011	3	EPA
MITCHELL SYSTEMS	bis(ethyl hexy)phthalate[c]	0.192	99.9985	1930	4.1	0.491	1	EPA
MITCHELL SYSTEMS	bis(ethyl hexy)phthalate[c]	0.416	99.996	1975	3.8	0.378	4	EPA
MITCHELL SYSTEMS	bis(ethyl hexy)phthalate[c]	0.169	99.993	2000	4.9	0.313	2	EPA
TWI	bis(ethyl hexy)phthalate[c,g]	0.00511	99.96	2030	0.4	0.127	2	EPA
TWI	bis(ethyl hexy)phthalate[c,g]	0.00429	99.951	2080	0.3	0.075	1	EPA
TWI	bis(ethyl hexy)phthalate[c,g]	0.00574	99.94	2070	0.6	0.048	3	EPA
TWI	bis(ethyl hexy)phthalate[c,g]	0.00261	99.88	1810	0.2	0.044	4	EPA
UPJOHN	bis(ethyl hexy)phthalate[c]	0.05	99.98	2040	0.9	0.094	2	EPA
UPJOHN	bis(ethyl hexy)phthalate[c]	0.13	99.98	2040	1.7	0.013	4	EPA
UPJOHN	bis(ethyl hexy)phthalate[c]	0.05	99.95	2040	1.2	0.08	3	EPA
CINCINNATI MSD	bromodichloromethane	0.4	99.995	2400	60.9	0.444	9	EPA
CINCINNATI MSD	bromodichloromethane	0.28	99.97	1650	5	0.107	7	EPA
ROSS INCINERATION	butyl benzyl phthalate	0.1	99.9996	2110	0.1	0.061	1	EPA
ROSS INCINERATION	butyl benzyl phthalate	0.027	99.999	2040	0.3	0.061	3	EPA
ROSS INCINERATION	butyl benzyl phthalate[g]	0.017	99.998	2090	0.3	0.077	2	EPA
MITCHELL SYSTEMS	butyl benzyl phthalate	0.169	99.995	2000	4.9	0.313	2	EPA
CONFIDENTIAL SITE B	butyl benzyl phthalate[g]	0.0227	99.9938	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	butyl benzyl phthalate[g]	0.0149	99.9923	1952	4.47	0.161	3	EPA
MITCHELL SYSTEMS	butyl benzyl phthalate[g]	0.00758	99.992	1930	4.1	0.491	1	EPA
MITCHELL SYSTEMS	butyl benzyl phthalate[g]	0.0064	99.973	1975	3.8	0.378	4	EPA
CONFIDENTIAL SITE B	butyl benzyl phthalate[g]	0.00416	99.92	1952	1.83	0.187	2	EPA
STAUFFER CHEMICAL	carbon tetrachloride	0.89	99.99998	1830	99.9	0.002	6	Private
McDONNELL DGLS	carbon tetrachloride	8.9	99.99998	1800	1.64	0.044	3	Private
STAUFFER CHEMICAL	carbon tetrachloride	0.82	99.99998	1830	99.9	0.0009	4	Private
STAUFFER CHEMICAL	carbon tetrachloride	0.85	99.99998	1830	99.9	0.001	7	Private
STAUFFER CHEMICAL	carbon tetrachloride	0.84	99.99998	1830	99.9	0.003	5	Private
McDONNELL DGLS	carbon tetrachloride	7.5	99.99997	1800	0.8	0.032	2	Private
McDONNELL DGLS	carbon tetrachloride	8.1	99.99996	1800	1.67	0.047	1	Private
DUPONT-DE	carbon tetrachloride	9.4	99.99994	1831	2.6	f	3	Private
DUPONT-DE	carbon tetrachloride	9.2	99.99994	1842	1.3	f	7	Private
DUPONT-DE	carbon tetrachloride	9.3	99.99993	1864	1.2	0.079	6	Private
McDONNELL DGLS	carbon tetrachloride	8.9	99.99992	1800	0.74	0.032	4	Private
DUPONT-DE	carbon tetrachloride	8.7	99.99992	1833	0.6	0.08	4	Private
DUPONT-DE	carbon tetrachloride	7.5	99.99992	1906	0.1	0.055	2	Private
DUPONT-DE	carbon tetrachloride	8.8	99.99991	1826	1.7	f	5	Private
CINCINNATI MSD	carbon tetrachloride	0.26	99.9999	2400	6.1	f	3	EPA
DUPONT-LA	carbon tetrachloride	5.38	99.99988	2640	0.6	0.004	2	EPA
DUPONT-LA	carbon tetrachloride	6.16	99.99986	2640	0.5	0.015	1	EPA
DUPONT-LA	carbon tetrachloride	5.27	99.99981	2640	0.9	0.011	3	EPA
DUPONT-DE	carbon tetrachloride	7.7	99.9994	1857	1.1	0.071	1	Private
ZAPATA INDUSTRIES	carbon tetrachloride	0.73	99.99911	1600	1.4	0.022	2	EPA
TWI	carbon tetrachloride[c]	0.379	99.99903	1810	0.2	0.044	4	EPA
3M	carbon tetrachloride	1.068	99.999	1985	0.2	0.091	4	Private
3M	carbon tetrachloride	1.031	99.999	1950	0.48	0.112	2	Private
3M	carbon tetrachloride	1.021	99.999	1890	0.8	0.08	10	Private
3M	carbon tetrachloride	0.99	99.999	1930	1.2	0.154	8	Private
3M	carbon tetrachloride	0.868	99.999	2030	0.44	0.0848	3	Private
3M	carbon tetrachloride	0.623	99.999	1905	0.3	0.047	6	Private
ZAPATA INDUSTRIES	carbon tetrachloride	0.61	99.999	1550	2.8	0.036	3	EPA
3M	carbon tetrachloride	0.596	99.999	1885	0.4	0.048	7	Private
3M	carbon tetrachloride	0.482	99.999	1915	0.5	0.047	5	Private
CINCINNATI MSD	carbon tetrachloride	0.16	99.999	1650	3.7	f	4	EPA
DOW CHEMICAL	carbon tetrachloride		99.999	1860	99.4		11302-2	Private

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
TWI	carbon tetrachloride[c,k]	0.377	99.9987	2050	h	h	7	EPA
TWI	carbon tetrachloride[c]	0.277	99.9987	2070	0.6	0.048	3	EPA
MITCHELL SYSTEMS	carbon tetrachloride[c]	0.243	99.9984	1975	3.8	0.378	4	EPA
TWI	carbon tetrachloride[c]	0.198	99.9984	2080	0.3	0.075	1	EPA
TWI	carbon tetrachloride[c]	0.228	99.9983	2030	0.4	0.127	2	EPA
MITCHELL SYSTEMS	carbon tetrachloride[c]	0.263	99.9981	2000	4.9	0.313	2	EPA
3M	carbon tetrachloride	0.881	99.998	1925	0.7	0.078	9	Private
3M	carbon tetrachloride	0.524	99.998	1985	0.86	0.0623	1	Private
ZAPATA INDUSTRIES	carbon tetrachloride	0.28	99.9972	1660	3.3	0.017	4	EPA
MITCHELL SYSTEMS	carbon tetrachloride[c]	0.242	99.997	1930	4.1	0.491	1	EPA
TWI	carbon tetrachloride[c,k]	0.53	99.9966	2120	h	h	8A	EPA
ROSS INCINERATION	carbon tetrachloride	0.16	99.9964	2110	0.1	0.061	1	EPA
ROSS INCINERATION	carbon tetrachloride	0.21	99.9961	2090	0.3	0.077	2	EPA
DOW CHEMICAL	carbon tetrachloride		99.996	1830	99.7		11302-3	Private
ROSS INCINERATION	carbon tetrachloride	0.2	99.9959	2040	0.3	0.061	3	EPA
UPJOHN	carbon tetrachloride	4.4	99.9954	2040	1.7	0.013	4	EPA
TWI	carbon tetrachloride[c,k]	0.44	99.9951	2140	h	h	8B	EPA
CINCINNATI MSD	carbon tetrachloride	0.22	99.995	1650	1.9	f	1	EPA
UPJOHN	carbon tetrachloride	3.6	99.994	2040	0.9	0.094	2	EPA
UPJOHN	carbon tetrachloride	4.4	99.9931	2040	1.2	0.08	3	EPA
CONFIDENTIAL SITE B	carbon tetrachloride[c]	0.132	99.9928	1952	1.83	0.187	2	EPA
TWI	carbon tetrachloride[c,k]	0.209	99.9926	2230	h	h	6	EPA
MITCHELL SYSTEMS	carbon tetrachloride[c]	0.223	99.984	2050	f	f	3	EPA
CONFIDENTIAL SITE B	carbon tetrachloride[c]	0.163	99.984	1952	0.64	f	1	EPA
ZAPATA INDUSTRIES	carbon tetrachloride	1.2	99.978	1570	2.2	0.03	1	EPA
CONFIDENTIAL SITE B	carbon tetrachloride[c]	0.142	99.976	1952	4.47	0.161	3	EPA
CINCINNATI MSD	carbon tetrachloride	0.11	99.96	2000	7.8	0.056	5	EPA
CONFIDENTIAL SITE B	carbon tetrachloride[c,l]	0.12	99.949	1776	h	h	4	EPA
CINCINNATI MSD	carbon tetrachloride	0.23	99.9	2400	89.7	f	6	EPA
CONFIDENTIAL SITE B	carbon tetrachloride[c,l]	0.118	99.63		h	h	5	EPA
TWI	chlordane	0.736	99.9999	2070	0.6	0.048	3	EPA
TWI	chlordane	0.66	99.9999	2030	0.4	0.127	2	EPA
TWI	chlordane	0.462	99.9998	2080	0.3	0.075	1	EPA
UNION CARBIDE	chlorobenzene	1.8	99.99979	1800	97.9	0.07	3	Private
UNION CARBIDE	chlorobenzene	1.7	99.99979	1800	98.4	0.064	12	Private
CIBA-GEIGY	chlorobenzene	29.52	99.9997	1800	99.9	0.21	1	Private
UNION CARBIDE	chlorobenzene	1.9	99.99962	1600	98.1	0.073	2	Private
UNION CARBIDE	chlorobenzene	1.4	99.99961	1600	98.2	0.094	1	Private
UNION CARBIDE	chlorobenzene	2	99.99959	1600	98.6	0.055	11	Private
UNION CARBIDE	chlorobenzene	1.8	99.99952	1800	98.2	0.071	4	Private
CIBA-GEIGY	chlorobenzene	29.52	99.9995	1800	99.9	0.14	3	Private
UNION CARBIDE	chlorobenzene	1.6	99.99949	1800	98.2	0.075	6	Private
CIBA-GEIGY	chlorobenzene	29.52	99.9994	1800	99.9	0.2	2	Private
UNION CARBIDE	chlorobenzene	1.6	99.99935	1800	98.3	0.061	5	Private
CIBA-GEIGY	chlorobenzene	29.52	99.9992	1800	99.9	0.19	4	Private
UNION CARBIDE	chlorobenzene	2.7	99.99907	1600	98.9	0.066	7	Private
UNION CARBIDE	chlorobenzene	2.7	99.99907	1600	98.9	0.048	8	Private
UNION CARBIDE	chlorobenzene	2.6	99.9988	1600	98.5	0.057	9	Private
UNION CARBIDE	chlorobenzene	1.5	99.9987	1800	98.5	0.056	10	Private
ZAPATA INDUSTRIES	chlorobenzene	0.4	99.9983	1660	3.3	0.017	4	EPA
CIBA-GEIGY	chlorobenzene	29.52	99.998	1800	99.9	0.14	5	Private
ZAPATA INDUSTRIES	chlorobenzene	0.79	99.9974	1550	2.8	0.036	3	EPA
ZAPATA INDUSTRIES	chlorobenzene	0.78	99.9956	1570	2.2	0.03	1	EPA
ZAPATA INDUSTRIES	chlorobenzene	0.76	99.9953	1600	1.4	0.022	2	EPA
TWI	chlorobenzene[g,k]	0.0167	99.9949	2140	h	h	8B	EPA
TWI	chlorobenzene[g,k]	0.0184	99.978	2120	h	h	8A	EPA
TWI	chlorobenzene[g]	0.0047	99.966	1810	0.2	0.044	4	EPA
TWI	chlorobenzene[g]	0.00858	99.965	2080	0.3	0.075	1	EPA
TWI	chlorobenzene[g]	0.00956	99.956	2070	0.6	0.048	3	EPA
UPJOHN	chlorobenzene	0.68	99.945	2040	1.7	0.013	4	EPA
UPJOHN	chlorobenzene	0.41	99.86	2040	1.2	0.08	3	EPA
TWI	chlorobenzene[g,k]	0.0152	99.73	2050	h	h	7	EPA
TWI	chlorobenzene[g]	0.0102	99.7	2030	0.4	0.127	2	EPA
TWI	chlorobenzene[g,k]	0.0174	99.6	2230	h	h	6	EPA
SMITH KLINE CHEM	chloroform	1.21	99.99999	1640	0.6	0.057	6	Private
SMITH KLINE CHEM	chloroform	1.1	99.99999	1620	0.2	0.027	7	Private
SMITH KLINE CHEM	chloroform	0.93	99.99999	1710	0.6	0.03	8	Private

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
CINCINNATI MSD	chloroform	1.32	99.9997	1650	3.7	f	4	EPA
CINCINNATI MSD	chloroform	1.72	99.9995	2400	6.1	0.123	3	EPA
CINCINNATI MSD	chloroform	1.09	99.9989	2000	7.8	0.056	5	EPA
CINCINNATI MSD	chloroform	1.8	99.998	2400	89.7	f	6	EPA
CINCINNATI MSD	chloroform	1.2	99.998	1650	1.9	f	1	EPA
DUPONT-LA	chloroform	0.33	99.9938	2640	0.5	0.015	1	EPA
DUPONT-LA	chloroform	0.404	99.9914	2640	0.9	0.011	3	EPA
DUPONT-LA	chloroform	0.229	99.987	2640	0.6	0.004	2	EPA
TWI	chloroform[c,g]	0.00224	99.944	2080	0.3	0.075	1	EPA
TWI	chloroform[c,g,k]	0.00476	99.92	2140	h	h	8B	EPA
TWI	chloroform[c,g,k]	0.00443	99.88	2120	h	h	8A	EPA
CONFIDENTIAL SITE B	chloroform[c,g]	0.0074	99.86	1952	1.83	0.187	2	EPA
TWI	chloroform[c,g]	0.00201	99.8	2070	0.6	0.048	3	EPA
TWI	chloroform[c,g]	0.00654	99.78	1810	0.2	0.044	4	EPA
CONFIDENTIAL SITE B	chloroform[c,g]	0.0154	99.7	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	chloroform[c,g,l]	0.00428	99.69	1776	h	h	4	EPA
CONFIDENTIAL SITE B	chloroform[c,g]	0.0102	99.66	1952	4.47	0.161	3	EPA
TWI	chloroform[c,g,k]	0.0082	99.1	2230	h	h	6	EPA
TWI	chloroform[c,g,k]	0.00478	99.02	2050	h	h	7	EPA
TWI	chloroform[c,g]	0.00283	98.2	2030	0.4	0.127	2	EPA
CONFIDENTIAL SITE B	chloroform[c,g,l]	0.00725	97.9		h	h	5	EPA
UPJOHN	chloromethane[c]	>0.2	99.9986	2040	0.9	0.094	2	EPA
UPJOHN	chloromethane[c]	>0.19	99.9975	2040	1.7	0.013	4	EPA
UPJOHN	chloromethane[c]	>0.12	99.9952	2040	1.2	0.08	3	EPA
UPJOHN	chlorophenyl isocyanate	2.8	99.9991	2040	1.7	0.013	4	EPA
DUPONT-LA	cis-dichlorobutene	1.76	99.99998	2640	0.9	0.011	3	EPA
DUPONT-LA	cis-dichlorobutene	1.39	99.99998	2640	0.6	0.004	2	EPA
DUPONT-LA	cis-dichlorobutene	1.63	99.9999	2640	0.5	0.015	1	EPA
ROSS INCINERATION	cresol(s)	0.12	99.9993	2110	0.1	0.061	1	EPA
ROSS INCINERATION	cresol(s)	0.091	99.9991	2040	0.3	0.061	3	EPA
ROSS INCINERATION	cresol(s)	0.074	99.999	2090	0.3	0.077	2	EPA
TWI	dibromomethane[k]	0.326	99.99992	2140	h	h	8B	EPA
TWI	dibromomethane[k]	0.292	99.99981	2120	h	h	8A	EPA
TWI	dibromomethane	0.0244	99.9987	2080	0.3	0.075	1	EPA
TWI	dibromomethane[k]	0.319	99.9936	2050	h	h	7	EPA
TWI	dibromomethane	0.159	99.982	1810	0.2	0.044	4	EPA
TWI	dibromomethane[k]	0.322	99.974	2230	h	h	6	EPA
TWI	dibromomethane	0.172	99.964	2070	0.6	0.048	3	EPA
TWI	dibromomethane	0.126	99.956	2030	0.4	0.127	2	EPA
OLIN	dichlordifluormethane	5	99.99	2088	0.7	0.052	2a,b,c	Private
OLIN	dichlordifluormethane	5	99.99	2095	1.2	0.031	3a,b,c	Private
CINCINNATI MSD	dichlorobenzene	0.11-0.17	99.998	2400	60.9	0.444	9	EPA
CINCINNATI MSD	dichlorobenzene	0.09-0.15	99.996	1650	5	0.107	7	EPA
CINCINNATI MSD	dichlorobenzene	0.05-0.15	99.99	2000	16	0.68	8	EPA
PENNWALT	dichlorofluoroethane	17.6	99.999	2320	1.3	0.006	22-3	Private
PENNWALT	dichlorofluoroethane	15.1	99.999	2370	1.4	0.006	23-2	Private
PENNWALT	dichlorofluoroethane	15	99.999	2260	0.72	0.044	22-4	Private
PENNWALT	dichlorofluoroethane	14.5	99.999	2340	1	0.007	23-3	Private
PENNWALT	dichlorofluoroethane	9.2	99.999	2380	0.9	0.005	23-1	Private
PENNWALT	dichlorofluoroethane	8.9	99.997	2340	1.1	0.036	22-1	Private
PENNWALT	dichlorofluoroethane	10.2	99.995	2350	1	0.014	22-2	Private
DUPONT-DE	dichloromethane	6.7	99.9999	1864	1.2	0.079	6	Private
DUPONT-DE	dichloromethane	6.1	99.9998	1826	1.7	f	5	Private
DUPONT-DE	dichloromethane	8	99.9997	1833	0.6	0.08	4	Private
DUPONT-DE	dichloromethane	7.1	99.9997	1831	2.6	f	3	Private
DUPONT-DE	dichloromethane	5.6	99.9997	1906	0.1	0.055	2	Private
DUPONT-DE	dichloromethane	4.6	99.9997	1842	1.3	f	7	Private
DUPONT-LA	dichloromethane	1.71	99.99941	2640	0.5	0.015	1	EPA
DUPONT-LA	dichloromethane	1.61	99.9991	2640	0.6	0.004	2	EPA
DUPONT-DE	dichloromethane	7.7	99.999	1857	1.1	0.071	1	Private
DUPONT-LA	dichloromethane	1.89	99.9988	2640	0.9	0.011	3	EPA
ROSS INCINERATION	dichloromethane[c]	0.67	99.989	2090	0.3	0.077	2	EPA
ROSS INCINERATION	dichloromethane[c]	0.36	99.978	2040	0.3	0.061	3	EPA
ROSS INCINERATION	dichloromethane[c]	0.23	99.968	2110	0.1	0.061	1	EPA
TWI	dichloromethane[g]	0.00627	99.918	2080	0.3	0.075	1	EPA
ZAPATA INDUSTRIES	dichloromethane	0.017	99.906	1600	1.4	0.022	2	EPA
TWI	dichloromethane[g,k]	0.00881	99.9	2140	h	h	8B	EPA

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
TWI	dichloromethane	0.021	99.88	2070	0.6	0.048	3	EPA
TWI	dichloromethane[g,k]	0.00832	99.83	2120	h	h	8A	EPA
TWI	dichloromethane[g]	0.00762	99.71	2030	0.4	0.127	2	EPA
TWI	dichloromethane[g]	0.0116	99.63	1810	0.2	0.044	4	EPA
TWI	dichloromethane[g,k]	0.0109	99.53	2050	h	h	7	EPA
TWI	dichloromethane[g,k]	0.013	99.51	2230	h	h	6	EPA
CONFIDENTIAL SITE B	diethyl phthalate	0.0572	99.974	1952	4.47	0.161	3	EPA
CONFIDENTIAL SITE B	diethyl phthalate	0.0524	99.962	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	diethyl phthalate	0.037	99.943	1952	1.83	0.187	2	EPA
AMERICAN CYANAMID	diphenyl amine[e]	0.58	99.9992	1198	0.007	0.069	3	EPA
AMERICAN CYANAMID	diphenyl amine[e]	0.54	99.9992	1198	0.007	0.175	5	EPA
AMERICAN CYANAMID	diphenyl amine[e]	0.62	99.999	1240	0.004	0.075	2	EPA
AKZO CHEMICAL	formaldehyde	10.03	99.998	1650	d	0.052	3-18	Private
DUPONT-WV	formaldehyde	9.7	99.998	1701	h	0.017	DIES-4	Private
DUPONT-WV	formaldehyde	10	99.997	1729	h	0.017	DIES-3	Private
AKZO CHEMICAL	formaldehyde	10.01	99.996	1620	d	0.037	1-18	Private
AKZO CHEMICAL	formaldehyde	10.24	99.995	1830	d	0.041	1-20	Private
DUPONT-WV	formaldehyde	7.5	99.995	1735	h	0.018	DIES-2	Private
AKZO CHEMICAL	formaldehyde	10.2	99.993	1830	d	0.043	3-20	Private
AKZO CHEMICAL	formaldehyde	10.14	99.993	1780	d	0.04	2-19	Private
AKZO CHEMICAL	formaldehyde	10.01	99.993	1830	d	0.04	2-20	Private
AKZO CHEMICAL	formaldehyde	10.09	99.992	1780	d	0.048	1-19	Private
AKZO CHEMICAL	formaldehyde	10.09	99.992	1780	d	0.04	3-19	Private
AKZO CHEMICAL	formaldehyde	10.05	99.992	1630	d	0.03	2-18	Private
CINCINNATI MSD	hexachlorobenzene[g]	<0.01-0.016	99.993	2400	89.7	f	6	EPA
CINCINNATI MSD	hexachlorobenzene[g]	<0.01-0.01	99.993	1650	3.7	f	4	EPA
CINCINNATI MSD	hexachlorobenzene[g]	<0.01-0.016	99.99	2000	0.8	0.123	2	EPA
CINCINNATI MSD	hexachlorobenzene[g]	0.01-0.026	99.99	2400	6.1	f	3	EPA
CINCINNATI MSD	hexachlorobenzene[g]	0.01	99.99	1650	1.9	f	1	EPA
CINCINNATI MSD	hexachlorobenzene[g]	0.01	99.99	2000	7.8	0.056	5	EPA
TWI	hexachlorobutadiene[g]	0.0144	99.98	1810	0.2	0.044	4	EPA
TWI	hexachlorocyclopentadiene	0.693	99.9996	1810	0.2	0.044	4	EPA
CINCINNATI MSD	hexachlorocyclopentadiene	0.37-0.56	99.999	1650	1.9	f	1	EPA
CINCINNATI MSD	hexachlorocyclopentadiene	0.24-1.6	99.998	2400	6.1	f	3	EPA
CINCINNATI MSD	hexachlorocyclopentadiene	0.25-0.71	99.996	2000	7.8	0.056	5	EPA
CINCINNATI MSD	hexachlorocyclopentadiene	0.069-0.76	99.996	2000	0.8	0.123	2	EPA
TWI	hexachlorocyclopentadiene[g]	0.00956	99.99	2070	0.6	0.048	3	EPA
TWI	hexachlorocyclopentadiene[g]	0.00786	99.99	2030	0.4	0.127	2	EPA
TWI	hexachlorocyclopentadiene[g]	0.0066	99.99	2080	0.3	0.075	1	EPA
CINCINNATI MSD	hexachlorocyclopentadiene[g]	0.01-1.2	99.97	2400	89.7	f	6	EPA
CINCINNATI MSD	hexachlorocyclopentadiene[g]	0.009-0.31	99.96	1650	3.7	f	4	EPA
UNION CARBIDE	hexachloroethane	6.4	99.99997	1600	98.2	0.094	1	Private
UNION CARBIDE	hexachloroethane	2.8	99.9999	1600	98.9	0.048	8	Private
UNION CARBIDE	hexachloroethane	2.7	99.9999	1600	98.9	0.066	7	Private
UNION CARBIDE	hexachloroethane	2.7	99.9999	1600	98.5	0.057	9	Private
UNION CARBIDE	hexachloroethane	2.1	99.9999	1600	98.6	0.055	11	Private
UNION CARBIDE	hexachloroethane	2	99.9999	1600	98.1	0.073	2	Private
UNION CARBIDE	hexachloroethane	2	99.9999	1800	98.2	0.075	6	Private
UNION CARBIDE	hexachloroethane	1.8	99.9999	1800	97.9	0.07	3	Private
UNION CARBIDE	hexachloroethane	1.8	99.9999	1800	98.2	0.071	4	Private
UNION CARBIDE	hexachloroethane	1.7	99.9999	1800	98.4	0.064	12	Private
UNION CARBIDE	hexachloroethane	1.6	99.9999	1800	98.3	0.061	5	Private
UNION CARBIDE	hexachloroethane	1.5	99.9999	1800	98.5	0.056	10	Private
CINCINNATI MSD	hexachloroethane	0.21-0.47	99.9997	2400	60.9	0.444	9	EPA
CINCINNATI MSD	hexachloroethane	0.22-0.77	99.9996	1650	5	0.107	7	EPA
CINCINNATI MSD	hexachloroethane	0.14-0.75	99.999	2000	16	0.68	8	EPA
CIBA-GEIGY	hexachloroethane	4.87	99.998	1800	99.9	0.21	1	Private
CIBA-GEIGY	hexachloroethane	4.87	99.997	1800	99.9	0.2	2	Private
CIBA-GEIGY	hexachloroethane	4.87	99.997	1800	99.9	0.14	3	Private
CIBA-GEIGY	hexachloroethane	4.87	99.995	1800	99.9	0.19	4	Private
CINCINNATI MSD	hexachloroethane[g]	0.01-0.023	99.994	2400	89.7	f	6	EPA
CINCINNATI MSD	hexachloroethane[g]	0.01-0.019	99.993	2000	0.8	0.123	2	EPA
CINCINNATI MSD	hexachloroethane[g]	0.01-0.014	99.992	1650	3.7	f	4	EPA
CIBA-GEIGY	hexachloroethane	4.87	99.992	1800	99.9	0.14	5	Private
CINCINNATI MSD	hexachloroethane	0.011-0.020	99.99	2400	6.1	f	3	EPA
CINCINNATI MSD	hexachloroethane[g]	0.01-0.018	99.99	2000	7.8	0.056	5	EPA
CINCINNATI MSD	hexachloroethane[g]	0.01-0.015	99.99	1650	1.9	f	1	EPA

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
DUPONT-LA	hexachloroethane[g]	0.045	99.99	2640	0.6	0.004	2	EPA
DUPONT-LA	hexachloroethane	0.044	99.99	2640	0.5	0.015	1	EPA
DUPONT-LA	hexachloroethane	0.0395	99.99	2640	0.9	0.011	3	EPA
UPJOHN	m-dichlorobenzene	2.1	99.922	2040	0.9	0.094	2	EPA
UPJOHN	m-dichlorobenzene	3.1	99.932	2040	1.7	0.013	4	EPA
UPJOHN	m-dichlorobenzene	2.3	99.905	2040	1.2	0.08	3	EPA
AMERICAN CYANAMID	m-dinitrobenzene[e]	0.31	99.99	1254	0.007	0.007	4	EPA
ROSS INCINERATION	MEK	0.86	99.99967	2110	0.1	0.061	1	EPA
ROSS INCINERATION	MEK	1.64	99.99932	2040	0.3	0.061	3	EPA
ROSS INCINERATION	MEK	0.79	99.9993	2090	0.3	0.077	2	EPA
MITCHELL SYSTEMS	MEK	0.273	99.9965	1930	4.1	0.491	1	EPA
MITCHELL SYSTEMS	MEK	0.422	99.9952	2000	4.9	0.313	2	EPA
MITCHELL SYSTEMS	MEK		99.988	2050	f	f	3	EPA
MITCHELL SYSTEMS	MEK	0.284	99.987	1975	3.8	0.378	4	EPA
ROSS INCINERATION	methyl pyridine	0.042	99.998	2090	0.3	0.077	2	EPA
ROSS INCINERATION	methyl pyridine	0.041	99.998	2040	0.3	0.061	3	EPA
ROSS INCINERATION	methyl pyridine	0.025	99.998	2110	0.1	0.061	1	EPA
AMERICAN CYANAMID	mononitrobenzene[e]	64	99.99991	1254	0.007	0.007	4	EPA
ROSS INCINERATION	N,N dimethylacetamide	1.9	99.9999	2040	0.3	0.061	3	EPA
ROSS INCINERATION	N,N dimethylacetamide	1.82	99.9999	2090	0.3	0.077	2	EPA
ROSS INCINERATION	N,N dimethylacetamide	0.83	99.9998	2110	0.1	0.061	1	EPA
TWI	naphthalene	0.379	99.996	1810	0.2	0.044	4	EPA
MITCHELL SYSTEMS	naphthalene[c,g]	0.0395	99.986	1975	3.8	0.378	4	EPA
MITCHELL SYSTEMS	naphthalene[c,g]	0.0148	99.98	2000	4.9	0.313	2	EPA
MITCHELL SYSTEMS	naphthalene[c,g]	0.0192	99.96	1930	4.1	0.491	1	EPA
DUPONT-LA	naphthalene[c,g]	0.009	99.1	2640	0.6	0.004	2	EPA
DUPONT-LA	naphthalene[c,g]	0.011	98	2640	0.5	0.015	1	EPA
DUPONT-LA	naphthalene[c,g]	0.006	97.4	2640	0.9	0.011	3	EPA
GULF OIL	naphthalene		99.998	1310	0.12	0.027	1	Private
GULF OIL	naphthalene		99.998	1320	0.12	0.053	2	Private
GULF OIL	naphthalene		99.998	1320	0.19	0.026	3	Private
ROSS INCINERATION	naphthalene[c]	0.036	99.994	2090	0.3	0.077	2	EPA
ROSS INCINERATION	naphthalene[c]	0.032	99.994	2110	0.1	0.061	1	EPA
ROSS INCINERATION	naphthalene[c]	0.024	99.991	2040	0.3	0.061	3	EPA
CONFIDENTIAL SITE B	naphthalene[c,g]	0.0177	99.927	1952	4.47	0.161	3	EPA
CONFIDENTIAL SITE B	naphthalene[c,g]	0.0174	99.85	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	naphthalene[c,g]	0.0118	99.81	1952	1.83	0.187	2	EPA
UPJOHN	o-dichlorobenzene	4	99.999	2040	0.9	0.094	2	EPA
UPJOHN	o-dichlorobenzene	6.4	99.999	2040	1.7	0.013	4	EPA
UPJOHN	o-dichlorobenzene	4.6	99.993	2040	1.2	0.08	3	EPA
UPJOHN	p-dichlorobenzene	5.6	99.999	2040	0.9	0.094	2	EPA
UPJOHN	p-dichlorobenzene	8	99.999	2040	1.7	0.013	4	EPA
UPJOHN	p-dichlorobenzene	5.9	99.995	2040	1.2	0.08	3	EPA
SCA CHEMICAL SER	PCB	27.5	99.99994	2212	2.5	f	19	Private
SCA CHEMICAL SER	PCB	26.7	99.99982	2231	1.4	0.075	17	Private
SCA CHEMICAL SER	PCB	19	99.9998	2225	3.4	f	21	Private
SCA CHEMICAL SER	PCB	22.1	99.99949	2247	2.2	f	20	Private
CINCINNATI MSD	pentachloroethane	0.42-0.81	99.9998	1650	5	0.107	7	EPA
CINCINNATI MSD	pentachloroethane	0.42-0.81	99.9998	2400	60.9	0.444	9	EPA
CINCINNATI MSD	pentachloroethane	0.27-0.83	99.9994	2000	16	0.68	8	EPA
MITCHELL SYSTEMS	phenol[c]	1.9	99.99996	2000	4.9	0.313	2	EPA
MITCHELL SYSTEMS	phenol[c]	2.73	99.9985	1930	4.1	0.491	1	EPA
ROSS INCINERATION	phenol[c,g]	0.012	99.997	2110	0.1	0.061	1	EPA
MITCHELL SYSTEMS	phenol[c]	1.72	99.996	1975	3.8	0.378	4	EPA
GULF OIL	phenol		99.996	1320	0.12	0.053	2	Private
ROSS INCINERATION	phenol[c,g]	0.006	99.993	2090	0.3	0.077	2	EPA
GULF OIL	phenol		99.993	1320	0.19	0.026	3	Private
ROSS INCINERATION	phenol[c,g]	0.005	99.992	2040	0.3	0.061	3	EPA
GULF OIL CORP.	phenol		99.991	1310	0.12	0.027	1	Private
CONFIDENTIAL SITE B	phenol[c]	0.169	99.989	1952	1.83	0.187	2	EPA
CONFIDENTIAL SITE B	phenol[c]	0.148	99.979	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	phenol[c]	0.249	99.976	1952	4.47	0.161	3	EPA
UPJOHN	phenyl isocyanate	17	99.99992	2040	0.9	0.094	2	EPA
UPJOHN	phenyl isocyanate	21	99.99992	2040	1.7	0.013	4	EPA
UPJOHN	phenyl isocyanate	16	99.9999	2040	1.2	0.08	3	EPA
AMERICAN CYANAMID	phenylene diamine	0.53	99.9992	1198	0.007	0.069	3	EPA

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
AMERICAN CYANAMID	phenylene diamine[a]	0.46	99.999	1198	0.007	0.175	5	EPA
AMERICAN CYANAMID	phenylene diamine[a]	0.23	99.997	1240	0.004	0.075	2	EPA
UPJOHN	phosgene	53.4	99.9985	2040	0.9	0.094	2	EPA
UPJOHN	phosgene	50.8	99.993	2040	1.2	0.08	3	EPA
UPJOHN	phosgene	20.2	99.981	2040	1.7	0.013	4	EPA
ROSS INCINERATION	phthalic anhydride[g]	0.008	99.99	2090	0.3	0.077	2	EPA
ROSS INCINERATION	phthalic anhydride[g]	0.007	99.99	2040	0.3	0.061	3	EPA
CINCINNATI MSD	tetrachloroethane	0.27	99.9998	2400	60.9	0.444	9	EPA
CINCINNATI MSD	tetrachloroethane	0.128	99.9997	1650	5	0.107	7	EPA
SMITH KLINE CHEM	tetrachloroethene	1.32	99.99999	1620	0.2	0.027	7	Private
SMITH KLINE CHEM	tetrachloroethene	0.98	99.99999	1710	0.6	0.03	8	Private
SMITH KLINE CHEM	tetrachloroethene	1.36	99.99997	1640	0.6	0.057	6	Private
CINCINNATI MSD	tetrachloroethene	0.38	99.999	2400	6.1	f	3	EPA
CINCINNATI MSD	tetrachloroethene	0.24	99.999	1650	1.9	f	1	EPA
CIBA-GEIGY	tetrachloroethene	5.03	99.997	1800	99.9	0.21	1	Private
CINCINNATI MSD	tetrachloroethene	0.26	99.997	1650	3.7	f	4	EPA
CIBA-GEIGY	tetrachloroethene	5.03	99.995	1800	99.9	0.2	2	Private
CIBA-GEIGY	tetrachloroethene	5.03	99.995	1800	99.9	0.14	3	Private
CIBA-GEIGY	tetrachloroethene	5.03	99.991	1800	99.9	0.19	4	Private
CINCINNATI MSD	tetrachloroethene	0.26	99.99	2000	7.8	0.056	5	EPA
CIBA-GEIGY	tetrachloroethene	5.03	99.982	1800	99.9	0.14	5	Private
CINCINNATI MSD	tetrachloroethene	0.34	99.97	2400	89.7	f	6	EPA
UNION CARBIDE	tetrachloroethylene	1.6	99.99986	1800	98.2	0.075	6	Private
UNION CARBIDE	tetrachloroethylene	1.7	99.99985	1800	98.4	0.064	12	Private
UNION CARBIDE	tetrachloroethylene	2.8	99.99984	1600	98.9	0.048	8	Private
UNION CARBIDE	tetrachloroethylene	1.8	99.99984	1800	97.9	0.07	3	Private
UNION CARBIDE	tetrachloroethylene	2.1	99.99983	1600	98.6	0.055	11	Private
UNION CARBIDE	tetrachloroethylene	2.7	99.99979	1600	98.5	0.057	9	Private
UNION CARBIDE	tetrachloroethylene	1.8	99.99977	1800	98.2	0.071	4	Private
UNION CARBIDE	tetrachloroethylene	1.6	99.99977	1800	98.3	0.061	5	Private
UNION CARBIDE	tetrachloroethylene	1.5	99.99977	1800	98.5	0.056	10	Private
UNION CARBIDE	tetrachloroethylene	2	99.99975	1600	98.1	0.073	2	Private
UNION CARBIDE	tetrachloroethylene	1.4	99.99972	1600	98.2	0.094	1	Private
DUPONT-LA	tetrachloroethylene	0.852	99.99972	2640	0.6	0.004	2	EPA
UNION CARBIDE	tetrachloroethylene	2.7	99.99966	1600	98.9	0.066	7	Private
DUPONT-LA	tetrachloroethylene	1.06	99.99948	2640	0.5	0.015	1	EPA
DUPONT-LA	tetrachloroethylene	0.834	99.99926	2640	0.9	0.011	3	EPA
CONFIDENTIAL SITE B	tetrachloroethylene[c]	0.398	99.99918	1952	4.47	0.161	3	EPA
ROSS INCINERATION	tetrachloroethylene	1.67	99.99912	2040	0.3	0.061	3	EPA
ROSS INCINERATION	tetrachloroethylene	0.78	99.9986	2110	0.1	0.061	1	EPA
McDONNELL DGLS	tetrachloroethylene	0.6	99.99779	1800	1.67	0.047	1	Private
ROSS INCINERATION	tetrachloroethylene	0.69	99.9977	2090	0.3	0.077	2	EPA
McDONNELL DGLS	tetrachloroethylene	0.57	99.9977	1800	0.8	0.032	2	Private
McDONNELL DGLS	tetrachloroethylene	0.64	99.99763	1800	1.64	0.044	3	Private
McDONNELL DGLS	tetrachloroethylene	0.64	99.9971	1800	0.74	0.032	4	Private
CONFIDENTIAL SITE B	tetrachloroethylene[c]	0.582	99.9968	1952	0.64	f	1	EPA
CONFIDENTIAL SITE B	tetrachloroethylene[c]	0.347	99.9966	1952	1.83	0.187	2	EPA
MITCHELL SYSTEMS	tetrachloroethylene[g]	0.00861	99.9929	2050	f	f	3	EPA
TWI	tetrachloroethylene[g]	0.0183	99.982	1810	0.2	0.044	4	EPA
TWI	tetrachloroethylene[g,k]	0.0044	99.966	2140	h	h	8B	EPA
TWI	tetrachloroethylene[g]	0.00567	99.965	2080	0.3	0.075	1	EPA
CONFIDENTIAL SITE B	tetrachloroethylene[c,l]	0.235	99.948	1776	h	h	4	EPA
CONFIDENTIAL SITE B	tetrachloroethylene[c,l]	0.29	99.937		h	h	5	EPA
TWI	tetrachloroethylene[g]	0.0124	99.88	2070	0.6	0.048	3	EPA
TWI	tetrachloroethylene[g,k]	0.00377	99.81	2050	h	h	7	EPA
TWI	tetrachloroethylene[g]	0.00636	99.78	2030	0.4	0.127	2	EPA
TWI	tetrachloroethylene[g,k]	0.0041	99.64	2230	h	h	6	EPA
DUPONT-LA	toluene	20.2	99.99993	2640	0.6	0.004	2	EPA
TWI	toluene[k]	9.87	99.99988	2140	h	h	8B	EPA
DUPONT-LA	toluene	21.9	99.99986	2640	0.9	0.011	3	EPA
DUPONT-LA	toluene	21.54	99.99986	2640	0.5	0.015	1	EPA
TWI	toluene[k]	11.03	99.99959	2120	h	h	8A	EPA
SMITH KLINE CHEM	toluene	3.86	99.99953	1620	0.2	0.027	7	Private
TWI	toluene	7.92	99.99946	2080	0.3	0.075	1	EPA
CIBA-GEIGY	toluene	60.58	99.9994	1800	99.9	0.21	1	Private
CONFIDENTIAL SITE B	toluene[c]	2.47	99.99923	1952	0.64	f	1	EPA

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
CIBA-GEIGY	toluene	60.58	99.9992	1800	99.9	0.2	2	Private
CIBA-GEIGY	toluene	60.58	99.9992	1800	99.9	0.14	3	Private
ROSS INCINERATION	toluene	4.04	99.99904	2110	0.1	0.061	1	EPA
ROSS INCINERATION	toluene	2.87	99.9987	2090	0.3	0.077	2	EPA
SMITH KLINE CHEM	toluene	3.2	99.9982	1710	0.6	0.03	8	Private
CIBA-GEIGY	toluene	60.58	99.998	1800	99.9	0.19	4	Private
TWI	toluene[k]	8.52	99.9979	2230	h	h	6	EPA
ROSS INCINERATION	toluene	2.74	99.9978	2040	0.3	0.061	3	EPA
TWI	toluene[k]	8.55	99.9976	2050	h	h	7	EPA
CIBA-GEIGY	toluene	60.58	99.997	1800	99.9	0.14	5	Private
SMITH KLINE CHEM	toluene	4.53	99.997	1640	0.6	0.057	6	Private
TWI	toluene	9.56	99.9963	2070	0.6	0.048	3	EPA
ZAPATA INDUSTRIES	toluene	0.42	99.9956	1660	3.3	0.017	4	EPA
CONFIDENTIAL SITE B	toluene[c,l]	0.748	99.994	1776	h	h	4	EPA
ZAPATA INDUSTRIES	toluene	0.073	99.9932	1550	2.8	0.036	3	EPA
CONFIDENTIAL SITE B	toluene[c]	1.62	99.9923	1952	4.47	0.161	3	EPA
TWI	toluene	6.01	99.9922	1810	0.2	0.044	4	EPA
ZAPATA INDUSTRIES	toluene	0.33	99.9914	1600	1.4	0.022	2	EPA
TWI	toluene	4.08	99.9908	2030	0.4	0.127	2	EPA
CONFIDENTIAL SITE B	toluene[c]	1.317	99.989	1952	1.83	0.187	2	EPA
CONFIDENTIAL SITE B	toluene[c,l]	1.3	99.982		h	h	5	EPA
MITCHELL SYSTEMS	toluene[c]	0.0618	99.979	1975	3.8	0.378	4	EPA
MITCHELL SYSTEMS	toluene[c]	0.0738	99.966	1930	4.1	0.491	1	EPA
MITCHELL SYSTEMS	toluene[c]	0.0957	99.957	2050	f	f	3	EPA
ZAPATA INDUSTRIES	toluene	0.11	99.952	1570	2.2	0.03	1	EPA
MITCHELL SYSTEMS	toluene[c]	0.105	99.941	2000	4.9	0.313	2	EPA
DUPONT-LA	trans-dichlorobutene	5.27	99.99992	2640	0.9	0.011	3	EPA
DUPONT-LA	trans-dichlorobutene	4.48	99.9999	2640	0.6	0.004	2	EPA
DUPONT-LA	trans-dichlorobutene	4.4	99.9999	2640	0.5	0.015	1	EPA
OLIN	trichlorfluormethane	14.85	99.9999	2095	1.2	0.031	3a,b,c	Private
OLIN	trichlorfluormethane	10.97	99.9998	2088	0.7	0.052	2a,b,c	Private
DOW CHEMICAL	trichlorobenzenes		99.995	1800	99.7		10272-1	Private
DOW CHEMICAL	trichlorobenzenes		99.992	1820	99.8		10272-2	Private
CINCINNATI MSD	trichloroethane	3.1	99.999	2400	60.9	0.444	9	EPA
CINCINNATI MSD	trichloroethane	0.96	99.985	1650	5	0.107	7	EPA
McDONNELL DGLS	trichloroethylene	18	99.99999	1800	1.64	0.044	3	Private
McDONNELL DGLS	trichloroethylene	21	99.99998	1800	1.67	0.047	1	Private
McDONNELL DGLS	trichloroethylene	9.5	99.99995	1800	0.8	0.032	2	Private
DUPONT-LA	trichloroethylene	0.277	99.99984	2640	0.5	0.015	1	EPA
ROSS INCINERATION	trichloroethylene	1.04	99.99963	2110	0.1	0.061	1	EPA
UPJOHN	trichloroethylene	4	99.99956	2040	1.7	0.013	4	EPA
McDONNELL DGLS	trichloroethylene	0.5	99.9995	1800	0.74	0.032	4	Private
TWI	trichloroethylene[k]	0.555	99.99924	2140	h	h	8B	EPA
TWI	trichloroethylene[k]	0.67	99.99921	2120	h	h	8A	EPA
DUPONT-LA	trichloroethylene	0.309	99.999	2640	0.6	0.004	2	EPA
UPJOHN	trichloroethylene	4	99.9989	2040	1.2	0.08	3	EPA
TWI	trichloroethylene	0.353	99.9989	1810	0.2	0.044	4	EPA
ZAPATA INDUSTRIES	trichloroethylene	0.52	99.9985	1550	2.8	0.036	3	EPA
UPJOHN	trichloroethylene	3.3	99.9983	2040	0.9	0.094	2	EPA
ZAPATA INDUSTRIES	trichloroethylene	0.71	99.9979	1600	1.4	0.022	2	EPA
ROSS INCINERATION	trichloroethylene	0.83	99.9969	2040	0.3	0.061	3	EPA
ROSS INCINERATION	trichloroethylene	0.47	99.9965	2090	0.3	0.077	2	EPA
TWI	trichloroethylene	0.178	99.9962	2080	0.3	0.075	1	EPA
MITCHELL SYSTEMS	trichloroethylene[c]	0.202	99.9959	2050	f	f	3	EPA
DUPONT-LA	trichloroethylene	0.198	99.9951	2640	0.9	0.011	3	EPA
ZAPATA INDUSTRIES	trichloroethylene	0.29	99.9946	1660	3.3	0.017	4	EPA
TWI	trichloroethylene	0.212	99.9945	2030	0.4	0.127	2	EPA
TWI	trichloroethylene[k]	0.29	99.9926	2050	h	h	7	EPA
TWI	trichloroethylene	0.277	99.9917	2070	0.6	0.048	3	EPA
MITCHELL SYSTEMS	trichloroethylene[c]	0.232	99.991	2000	4.9	0.313	2	EPA
TWI	trichloroethylene	0.956	99.989	2230	h	h	6	EPA
MITCHELL SYSTEMS	trichloroethylene[c]	0.222	99.985	1930	4.1	0.491	1	EPA
MITCHELL SYSTEMS	trichloroethylene[c]	0.223	99.984	1975	3.8	0.378	4	EPA
CONFIDENTIAL SITE B	trichloroethylene[c]	0.136	99.983	1952	1.83	0.187	2	EPA
CONFIDENTIAL SITE B	trichloroethylene[c]	0.166	99.981	1952	0.64	f	1	EPA
ZAPATA INDUSTRIES	trichloroethylene	1.1	99.979	1570	2.2	0.03	1	EPA

Table 1. (continued)

SITE	POHC	POHC CONC,%[a]	DRE,%[a]	TEMP, °F	HCL, lb/h[b]	TSP, gr/dscf	TEST No.	SPONSOR
CONFIDENTIAL SITE B	trichloroethylene[c,j]	0.124	99.949	1776	h	h	4	EPA
CONFIDENTIAL SITE B	trichloroethylene[c]	0.147	99.8	1952	4.47	0.161	3	EPA
CONFIDENTIAL SITE B	trichloroethylene[c,l]	0.123	99.8		h	h	5	EPA

[a]For those runs in which a range of POHC waste feed concentrations were tested, only the lowest reported DRE is listed.
[b]HCl values for Dow, Stauffer Chemical, and Upjohn are listed as % removal, not lb/h.
[c]Sampling and/or analytical problems; data suspect.
[d]None detected; limit of detection unknown.
[e]Temperature reading suspect—may be low by 300°F.
[f]Not reported.
[g]Low POHC concentration (200 ppm or less) in waste feed.
[h]Not measured.
[i]Abnormal operating conditions—low temperature.
[j]Abnormal operating conditions—unspecified.
[k]Abnormal operating conditions—waste feed rate increased and combustion air distribution changed in attempt to increase CO and THC emissions.

Particulate and Hydrogen Chloride Emissions

Emissions of particulate matter and HCl are limited by 40 CFR 264.343 as follows:

Particulate matter	0.08 gr/dscf corrected to 7 percent O_2
HCl	4 lb/h, or an HCl removal efficiency of at least 99 percent

Although these emissions are generally a function of the ash and chloride contents of the waste burned, the outlet concentration also depends on the exhaust gas control system. Because control systems varied from site to site, correlating the particulate and HCl emissions with input concentrations is impossible. Although the available data do not permit the development of such a relationship, they do indicate that, in general, the HCl and particulate emission limits are achievable. Data from the EPA tests suggest that any facility firing wastes with ash content greater than 0.5 percent will need a particulate control device to meet the standard.

Other Results

Other important findings from the incineration tests conducted by EPA relative to (1) heat of combustion, (2) carbon monoxide (CO), total hydrocarbons (THC), and dioxin emissions, and (3) the sampling and analysis of waste feed and stack gases are presented below:[2]

Heat of Combustion—

- Analysis of the data collected in the EPA program showed no clear correlation between DRE and heat of combustion for the POHCs tested.

CO, THC, and Dioxin Emissions—

- CO and THC were monitored on a continuous basis to assess their utility as indicators of incinerator performance. The analysis indicates that CO and THC may provide some indication of changes in incinerator performance and gross malfunctions in the combustion process. However, under the conditions of these tests CO and THC levels did not appear to be good predictors of POHC emissions or DRE, either across the plants tested or at a specific site, for DREs in the vicinity of 99.99 percent. It should also be pointed out that these tests were not conducted in a parametric fashion specifically designed to determine if such a correlation could be found.

- Of six sites that were tested by EPA for tetra- and penta-chlorinated dioxins and furans, dioxins were found at one site and furans were found at three sites. No 2,3,7,8-TCDD was detected. The maximum concentrations detected were 0.06 ng/liter of chlorinated furans and 0.02 ng/liter of chlorinated dioxins.

Sampling and Analysis—

- The VOST method used in the EPA tests provided a consistent and reliable data base when operated by personnel familiar with the apparatus and procedures. Proper use of these procedures was critical to obtaining reliable data.

- Of the two methods used in the EPA program for sampling volatile organics in the stack—VOST and gas bags—the VOST method provided lower blank values than gas bags, resulting in a higher percentage of quantifiable data points. Also the VOST method was less cumbersome and less prone to contamination than gas bags.

- Hazardous waste samples contain a complex matrix of compounds which present a variety of analytical difficulties. Analysis by a gas chromatograph/mass spectrometer (GC/MS) was highly successful for identifying Appendix VIII compounds in the waste streams and effluents. Prescreening by a gas chromatograph/flame ionization detector (GC/FID) was useful when analyzing waste streams.

- Because small concentrations of organics must be

measured in stack gases, sample contamination can present significant problems. Careful control blanks and well defined blank correction procedures are required.

- The results of the external and internal quality assurance program used in the EPA study indicate that established quality assurance procedures were followed and the overall quality of laboratory and field work was adequate to meet the objectives of the study.

- Evaluation of the QA/QC data for the eight incinerator tests indicated low or erratic recoveries in the analyses of phenol, cis- and trans-1,2,-dichlorobutene, naphthalene, aniline, and bis(2-ethylhexyl)phthalate for the complex waste feed matrices encountered during this program. Caution should be used when evaluating these compounds as POHCs during actual trial burns.

- The results from waste sampling and analysis at plants where Appendix VIII compounds were spiked into the liquid waste feed line indicate that inadequate mixing and, as a result, nonrepresentative waste feed samples may be a problem at some facilities. One approach used to alleviate the problem was the use of in-line mixers. This approach was successful at the one facility where it was used during the program.

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RCRA Exemptions, Waivers, and Petitions for Hazardous Waste Incinerators

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Introduction

Several specialized exemptions and waivers are available to permit applicants based primarily on incinerator design and/or waste feed characteristics. The descriptions which follow are based on the Federal RCRA regulations, 40 C.F.R. Parts 260-264 and 270. In States that have been authorized by EPA to implement the RCRA program, State regulations have superseded the federal requirements, except as noted. In most instances there is little practical difference between the two regulations. However, some States may have more limited exemptions or have eliminated some exemptions entirely. It is important to remember that while State requirements may be more restrictive than those described here, they cannot be any broader in scope.

Even when identical regulations apply, there is sufficient discretionary authority to allow varying interpretations from State to State and even among EPA Regions. *The permit applicant should always review prospective exemptions and variances with the responsible permitting authority before submitting a Part B permit application.*

General Petitions

This provision is applicable to all hazardous waste treatment, storage and disposal facilities. 40 C.F.R. §260.20 provides that any affected person may petition the EPA Administrator to modify or revoke any regulatory provision of RCRA. Each petition must be submitted to the Administrator by certified mail and must include:

1. The petitioner's name and address;
2. A statement of the petitioner's interest in the proposed action;
3. A description of the proposed action, including (where applicable) suggested regulatory language; and
4. A statement of need and justification for the proposed action, including supporting tests, studies, or other information.

EPA's approval or denial of these petitions follows formal rulemaking procedures including proposal of a tentative determination in the *Federal Register*, consideration of public comments, and final rulemaking notice in the *Federal Register*. This authority is not delegated to authorized State RCRA programs.

Delisting

This provision is also applicable to all hazardous waste treatment, storage and disposal facilities. It is essentially a subcategory of general petitions as described above.

In order to understand the meaning of waste delisting, it is necessary to understand the distinction between "listed" and "characteristic" wastes. Listed wastes are those designated in 40 C.F.R. Part 261, Subpart D and identified by EPA Waste Codes F, K, U or P. "F" wastes are particular waste types, largely spent solvents, generated by non-specific sources. "K" wastes are various waste streams generated by specific manufacturing processes. "U" and "P" wastes both describe discarded or off-specification commercial chemical products including container and spill residues thereof. ("P" wastes are *acutely* hazardous, "U" wastes are hazardous.) Listed wastes, including all mixtures and treatment residues of listed wastes, are classified as hazardous wastes regardless of their actual chemical characteristics.

Characteristic wastes are those designated in 40 C.F.R. Part 261, Subpart C with an EPA Waste Code beginning with D. They are divided into four categories:

Characteristic	EPA Waste Code
Ignitable	D001
Corrosive	D002
Reactive	D003
EP Toxic	D004 thru D017

These classifications are based entirely on the waste's chemical properties. The generating process is generally not relevant. Unlike listed wastes, mixtures and residues of characteristic wastes are not hazardous wastes unless

the mixture or residue also exhibits one of the characteristics.

Any person may petition the EPA Administrator to exclude a waste at a particular generating facility from classification as a listed waste. To be successful, the petitioner must demonstrate that the waste does not meet any of the criteria for which it was listed as a hazardous waste, nor does it contain any other hazardous constituents which warrant retaining the hazardous waste classification.

A delisted waste is excluded from all RCRA permitting requirements unless it exhibits one or more of the hazardous waste characteristics (*i.e.*, ignitability, corrosivity, or reactivity). [Note: A waste exhibiting the fourth hazardous waste characteristic, EP toxicity, would not qualify for delisting.] If it does exhibit one or more of the characteristics, a permit is required, but most of the incinerator requirements, including performance standards for DRE, HCl and particulate emissions, do not apply (see I-C-R Exemption).

Although delisting can be applicable to wastes as generated, in the realm of incineration it is more likely to be applied to ash and/or air pollution control residues generated during incineration. Since any residue resulting from the treatment of a listed hazardous waste retains the same listing as the original waste [see 40 C.F.R. §261.3(c)(2)(i)], it is subject to the same treatment, storage and disposal requirements as the original waste. Some incinerators generate very large quantities of ash and air pollution control device residues. If it can be shown that those wastes qualify for delisting, there can be significant reductions in the overall cost of incineration.

Delisting petitions may only be approved by the EPA Administrator or his designee. State authorizations do not include this authority at the present time. Petition procedures are detailed in 40 C.F.R. §260.22. They require that the applicant supply analyses of a sufficient number of waste samples (at least four) taken over a period of time so as to characterize both the composition and variability of the waste. Consult the Code of Federal Regulations and the appropriate regulatory agency for more detailed application requirements.

Like general rulemaking petitions, delisting decisions follow formal rulemaking procedures including proposal in the Federal Register, consideration of public comments, and final rulemaking notice in the *Federal Register*.

Variances for Classification as a Boiler

Under the definitions in §260.10, all enclosed devices using controlled flame combustion for treatment of hazardous wastes fall into one of three categories. To be a "boiler", a unit must:

1. Have provisions for recovering and exporting energy in the form of steam or other heated fluids;
2. Have a combustion chamber and primary energy recovery section that are of "integral design" (incinerators with waste heat boilers do not meet this criterion);
3. Maintain a thermal efficiency of at least 60 percent; and
4. Utilize at least 75 percent of the recovered energy on an annual basis.

The integral design requirement notwithstanding, process heaters and fluid bed combustion units are not precluded from classification as boilers.

To be an "industrial furnace", the unit must be one of the specific process operations listed in §260.10 (*e.g.* cement kiln, lime kiln, blast furnace, etc.). All units which are not boilers or industrial furnaces are classified as "incinerators."

Boilers and industrial furnaces which burn wastes for purposes of heat recovery are not presently subject to any RCRA performance standards or permitting requirements. Those units which burn low-Btu (*i.e.* less than 8000 Btu per pound) wastes for purposes of disposal are subject to the incinerator permit requirements of Part 264, Subpart O. Blending of low-Btu wastes with high heating value materials for the purpose of avoiding regulation under Subpart O is prohibited.

Section 260.32 of the RCRA regulations provides that the EPA Regional Administrator may determine on a case-by-case basis that certain units are boilers, even though they do not otherwise meet the definition of "boiler", after considering the following:

1. The extent to which the unit recovers and exports useful energy; and
2. The extent to which the combustion chamber and energy recovery units are of integral design; and
3. The energy recovery efficiency of the entire system; and
4. The extent to which the exported energy is utilized; and
5. The extent to which the unit is in common use as a boiler; and
6. Other factors, as appropriate.

When evaluating an application for a variance from classification as a boiler, the Regional Administrator is required to follow the same administrative procedures as are required for processing a RCRA permit. That is, he must issue a tentative decision accompanied by newspaper and radio advertisement in the affected area. After a 30-day public comment period and a public hearing, if appropriate, he must issue a final decision. This is a final action and may not be appealed within the Agency.

This variance provision was made to allow development of unique or innovative boiler designs. It is probably not applicable to any existing units.

It should be noted that performance standards for all boilers are currently under development by EPA. When in place, those standards will remove much of the advantage that a boiler classification has over that for an incinerator. However, some procedural advantages may remain. It is likely that the boiler standards will provide two different permitting tracks. Boilers burning "clean" wastes (*i.e.* low metals and halogen contents, high heat content) may qualify for a permit-by-rule that will not require a trial burn. All other wastes would be subject to trial burn requirements much like those currently in effect for incinerators.

Promulgation of final boiler standards is being projected for mid- to late-1987. This discussion is, of course, speculative at this time. It is provided only so that potential variance applicants may more fully evaluate each option and its resultant benefit.

I-C-R Exemption

This is the most widely applicable incinerator exemption. In order to qualify, an incinerator must burn only ignitable, corrosive or certain reactive wastes. A qualifying incinerator must obtain a RCRA incinerator permit, but the permit is limited to a waste analysis plan and a closure plan. No operating or emission standards are imposed and no trial burn is required [see 40 C.F.R. 264.340(b) and (c)].

The following wastes qualify for this exemption provided that they do not contain any of the hazardous constituents listed in Part 261, Appendix VIII:

1. Those that are listed in Part 261, Subpart D solely because they are ignitable (Hazard Code I) and/or corrosive (Hazard Code C);

2. Those that are listed in Part 261, Subpart D solely because they are reactive (Hazard Code R), *and* they do not generate toxic gases when reacted, *and* they are not burned simultaneously with any other hazardous wastes;

3. Those that are hazardous solely because they exhibit the characteristic of ignitability (Waste Code D001) and/or corrosivity (Waste Code D002) as specified in Part 261, Subpart C; and

4. Those that are hazardous solely because they exhibit the characteristic of reactivity (Waste Code D003) as specified in Part 261, Subpart C *and* they do not generate toxic gases when reacted, *and* they are not burned simultaneously with any other hazardous wastes.

The permitting authority may also grant the exemption to any incinerator which meets the above criteria except that "insignificant" concentrations of Appendix VIII constituents are present. This determination of "insignificance" is entirely at the discretion of the permitting authority. No firm criteria exist. It has been suggested that anything below 100 ppm be considered insignificant for most organics. For some constituents (*e.g.* polychlorinated dioxins and dibenzofurans) much lower levels may be considered significant. For some less toxic constituents (*e.g.* toluene), concentrations in the 1000 ppm range may be insignificant.

In addition to toxicity of the waste constituent, the permit writer may consider other factors such as dispersion characteristics of the exhaust plume, size of the exposed population, incremental human health risk associated with the emission, and other environmental impacts.

It should be noted that any waste which is listed in Part 261, Subpart D due to the presumed presence of toxic constituents cannot be granted an I-C-R exemption regardless of the actual concentration of those constituents in the waste. If the applicant can demonstrate a sufficiently low concentration of toxic constituents, these wastes may be "delisted" as previously described.

Data in Lieu of a Trial Burn

For similar incinerators burning similar wastes, §270.19(d) requires the permit writer to use trial burn results from one incinerator to develop permit conditions for the other incinerator, if requested to do so by the applicant and if he finds that the previous trial burn data is sufficient. It is the determination as to what constitutes "similar" wastes and incinerator designs that leads to perhaps the greatest divergence of opinion among incinerator permit writers. Some permit writers contend that the provision is only applicable to identical units at the same facility burning identical wastes under identical conditions. Others take a much more liberal approach. EPA's Office of Solid Waste is currently reviewing the issue with the intent of developing a more consistent national approach.

The *Guidance Manual for Hazardous Waste Incinerator Permits* ("Permit Writer's Manual"), U.S. EPA, March 1983, provides some guidance as to the criteria which may be useful in evaluating similarity. It suggests the following for evaluating wastes:

1. Heating Value —It must be equal to or higher than that used in the trial burn.

2. Hazardous Constituents—The proposed waste must not contain significant quantities of any hazardous constituents considered more difficult to incinerate than those used as principal organic hazardous constituents (POHCs) during the trial burn.

3. Organic Chlorine Content—It must be less than or equal to the trial burn waste.

4. Ash Content—It must be less than or equal to the trial burn waste.

Some additional criteria which may be applicable are:

1. Viscosity—For atomized liquid injection incinerators, it should be less than or equal to the trial burn waste.

2. Solids Content—Particularly for injected liquid wastes, it should be less than or equal to the trial burn waste.

If it is determined that the wastes are similar, it is then necessary to evaluate whether the incinerators are similar in design, construction, and maintenance. The Permit Writer's Manual suggests that *all* of the following criteria must be met for units to be considered similar:

1. Type—For obvious reasons, both incinerators must be of the same type (*e.g.* liquid injection, rotary kiln, etc.).

2. Components and Dimensions—Combustion zone volume and cross sectional area should be ±20% of the other incinerator. Linear dimensions of major components should conform within ±10%.

3. Combustion Zone Temperature—Should be no more than 20°C (36°F) less than, nor 200°C (360°F) more than, that of the trial burn incinerator.

4. Excess Air and Air/Waste Feed Ratio—Excess air rate should be no less than, nor more than 50% higher than, that of the trial burn incinerator. Air/waste feed ratio should differ by no more than 10%.

5. Residence Time—Should be no more than 5% less nor 100% more than that of the trial burn incinerator.

6. Air Pollution Control Devices (APCDs)—These should be of the same type for both incinerators. Liquid to gas ratios should be within ±20%.

7. Auxiliary Fuel Use—Both incinerators should use the same fuel type with waste/fuel ratios within ±5%.

When evaluating these factors it is important that decisions be based on updated, "as built" drawings and actual operating conditions as opposed to design drawings and design operating conditions. Even identically designed incinerators are frequently modified in the field resulting in varying performance. Some other factors which may be useful when assessing similarity include:

1. Maintenance—Have refractory surfaces, kiln seals, nozzles and other components been similarly maintained at both incinerators? The use of "as built" drawings will aid in this evaluation.

2. Burners—All burners should be similar in design and operation (*e.g.* size, atomizing fluid, atomizing fluid pressure).

3. Carbon Monoxide Level—This should be less than or equal to that of the trial burn incinerator for both long-term average and short-term peaks.

4. Other APCD Operating Parameters—Each type of APCD operation should be fully characterized. Such parameters as pressure drop, pH, and power use may affect performance in addition to the liquid/gas ratio. Critical operating parameters for each equipment type are well documented in the air pollution control literature.

5. Controls—All monitoring and control systems should be similar. This is particularly important for any automated control logic.

Due to the wide variability in possible interpretations of similarity, it is highly recommended that any applicant wishing to pursue this course meet with the responsible permit writer prior to preparing the RCRA application. At that time, both parties should establish the specific criteria to be used for evaluating similarity.

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