Application of Pulse Combustion to Incineration of Liquid Hazardous Waste

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16. ABSTRACT The report gives results of a study to determine the effect of acoustic pulsations on the steady-state operation of a pulse combuster burning liquid hazardous waste. A horizontal tunnel furnace was retrofitted with a liquid injection pulse combustor that burned No. 2 fuel oil. The fuel oil was doped with surrogate principal organic hazardous constituents (POHCs). The POHCs used were carbon tetrachloride and chlorobenzene. Baseline conditions were tested when only fuel oil was burned as well as hazardous waste operations. For each test condition, the burner was operated in both a pulsing and nonpulsing mode. Large amplitude acoustic pulses were generated by adjusting the burner frequency to match the natural frequency of the combustion chamber. The combustion gases were sampled to quantify organic and particulate emissions. The results showed destruction and removal efficiency (DRE) values that were greater than six nines (99.9999%) for both pulsing and nonpulsing operations. The pulse combustor for this study was equipped with a fuel vaporization unit which may have enhanced the destruction capabilities of the burner. It is not known if operating without a vaporizer or under non-ideal combustion conditions would degrade burner performance.

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ABSTRACT

The purpose of this study was to determine the effect of acoustic pulsations on the steady-state operation of a pulse combustor burning liquid hazardous waste. A horizontal tunnel furnace was retrofitted with a liquid injection pulse combustor. The pulse combustor burned No. 2 fuel oil that was doped with principal organic hazardous constituents (POHCs). The POHCs that were used were carbon tetrachloride and chlorobenzene.

Baseline conditions were tested when only fuel oil was burned as well as hazardous waste operations. For each test condition, the burner was operated in a both a pulsing and nonpulsing mode. Large amplitude acoustic pulsations were generated by adjusting the burner frequency to match the natural frequency of the combustion chamber. Sampling of the combustion gases was done to quantify organic and particulate emissions.

The results showed Destruction and Removal Efficiency (DRE) values that were greater than six-nines (99.9999 percent) for both pulsing and nonpulsing operations. The pulse combustor for this study was equipped with a fuel vaporization unit which may have enhanced the destruction capabilities of the burner. It is not known if experiments without a vaporizer or operating the pulse combustor under non-ideal combustion conditions would help determine if acoustic pulsations can improve burner performance compared to the nonpulsed operation.

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SECTION 1

INTRODUCTION

1.1 SCOPE AND APPLICATION

Incineration is often utilized for the effective disposal of hazardous wastes. The performance of an incinerator is measured by how completely the principal organic hazardous compounds (POHCs) are destroyed, and also by how completely the intermediate degradation products are oxidized. For the ideal case of 100 percent combustion efficiency, air emissions from the burning of pure hydrocarbons would consist only of carbon dioxide and water. However, complete combustion is only a theoretical concept. Therefore, depending on the waste being treated, Agency regulations require 99.99% or 99.9999% destruction of the POHCs. Due to the growing public concern about incineration, and in particular hazardous waste incineration, research is continuing to look at ways of improving combustion efficiencies, thereby minimizing the emissions of potentially toxic compounds.

The purpose of this research was to determine if a pulse combustor could improve the organic destruction capabilities of a pilot-scale research furnace. This report discusses the results of experiments conducted on a horizontal tunnel furnace that was retrofitted with a tunable pulse combustor. The combustor was designed to burn No. 2 fuel oil which was

doped with surrogate liquid wastes. The exhaust combustion gases were sampled and analyzed to determine what effect large amplitude resonant pulsations have on hazardous waste incineration performance parameters.

Previous work on the application of pulse combustion to hazardous waste incineration (Stewart et al., 1991) has shown that the excitation of pulsations inside a Rotary Kiln Incinerator Simulator reduced soot emissions during incineration of toluene and polyethylene by 50 to 75 percent. Also, the carbon monoxide (CO) and total hydrocarbon (THC) levels were reduced during polyethylene incineration. The conclusions from this previous study were that the introduction of acoustic pulsations has a strong tendency to reduce the amount of unburned material exiting the combustion chamber. However, no detailed chemical analyses of the stack gas were undertaken. Therefore, the quantity and composition of products of incomplete combustion (PICs) were not determined. The pulse combustor for this previous work utilized natural gas as the primary fuel, and surrogate hazardous wastes were introduced in a batch mode.

For the experimental research in this study, a liquid injection pulse combustor was tested during the steady-state burning of a surrogate liquid waste stream. Continuous emission monitoring of combustion gases was done as well as volatile and semivolatile organic analyses. The results were utilized to determine the effect of resonant pulsations on the thermal destruction of selected organic compounds. In addition, a detailed chemical screening procedure was done to characterize and quantify the PICs for both the pulsating and nonpulsating modes of operation.

1.2 HAZARDOUS WASTE INCINERATION

The United States Environmental Protection Agency (EPA) conducted a National Hazardous Waste Survey in 1986. According to the survey (Behmanesh et al., 1992), approximately 4 million tons per year of hazardous waste is sent to various thermal treatment facilities. The thermal technologies include direct incineration, fuel blending, and reuse as a fuel. The survey also concluded that, of the 260 operating incinerators within the United States, 129 were liquid injection units. The study showed that most of the liquid hazardous waste is generated from the chemical manufacturing industry.

The Resource Conservation and Recovery Act (RCRA) mandates that the EPA set standards for hazardous waste incineration. The operational standards include continuous on-line monitoring of process parameters such as temperature and carbon monoxide emissions. The major performance parameter is the destruction and removal of toxic organic compounds which are contained in the waste stream. Specifically, RCRA regulations state that hazardous waste incinerators must demonstrate a destruction and removal efficiency (DRE) of four-nines (99.99 percent) or higher. This type of demonstration is done through a trial burn which is the primary step in the RCRA incinerator permitting process.

DRE is defined in the Code of Federal Regulations (CFR) by the following equation:

$$DRE = [(W_{in} - W_{out})/ W_{in}] \times 100 \text{ (percent)}$$

where W_{in} = mass feed rate of the POHC in the waste stream fed to the incinerator

                       W_{out} = mass emission rate of the POHC in the stack gas

Most well operated incinerators, including liquid injection systems, are capable of achieving the 99.99 percent DRE standard. Trial burn performance data (Oppelt, 1987) has shown that well-designed thermal destruction units should be able to demonstrate high DRE if sufficient temperature, oxygen, and feed controls are maintained. However, even in steady-state operations, conditions can exist within the combustion chamber which prevent organic destruction from occurring. One such condition that can have a negative effect on incinerator efficiency is inadequate mixing of combustion gases, fuel, and waste. Research has shown (Lee, 1988) that, at temperatures above 871°C (1600°F), combustion reactions may not be limited by the chemical oxidation kinetics, but rather by the mixing of oxygen with the organic fuel. Poor mixing within the combustion chamber can lower the overall efficiency due to oxygen-deficient pockets being formed within the flame zone.

To enhance the destruction performance of hazardous waste incinerators, most facilities operate under excess air conditions. However,

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even with an excess oxygen supply, the formation of potentially toxic PICs has been identified as a consequence of inadequate mixing between the combustibles and oxidant (EPA Science Advisory Board, 1989). The focus of this research was to determine if large amplitude acoustic pulsations could improve air/fuel mixing in the combustion chamber, and therefore improve the organic destruction capabilities of a liquid injection incineration system.

1.3 PULSE COMBUSTION

Pulse combustion refers to a combustion process that varies in a periodic manner. Pulse combustion is a relatively old technology. One of the first applications of a pulse combustor was for the engine that propelled the World War II "buzz bomb" (Reader, 1977). Today, a significant market for pulse combustors is in the area of space and water heaters. The Lennox® pulse furnace is an example of pulse combustion technology being utilized in home heating applications.

Pulsating combustion occurs when the heat released by a combustion process spontaneously excites a pressure wave within the combustion chamber. When this pressure wave is in phase with periodic heat release, pressure and gas velocity oscillations occur. In order to excite large amplitude pulsations within a pulse combustor, the frequency at which it operates must equal one of the natural acoustic modes of the combustion chamber. When these frequencies are matched, resonant

pulsations are excited in the combustion section as well as the tailpipe portion of the pulse burner.

Studies on various pulse combustor designs (Zinn, 1985) have shown that combustion intensity, convective heat transfer, and mass transfer rates can be increased. Pulse combustors have also been shown to have decreased levels of nitrogen oxides (NO_x) emissions (Bartok et al., 1988). Due to their increased combustion efficiencies, pulse combustors result in fuel savings and provide for lower operating costs.

One of the important benefits of a pulse combustor for hazardous waste incineration is the improved mixing of combustion gases. The resonant pulsations cause significant gas turbulence within the combustion zone. The effect has also been noted downstream of the primary chamber in the tail pipe section of a pulse burner (Dec and Keller, 1986). This improved mixing should minimize the formation of any cold spots or oxygen deficient areas within the combustion chamber.

Based on these findings, it appears that pulse combustion should improve the performance of a hazardous waste incinerator. The thermal destruction of hazardous waste should be enhanced due to the improvements in mass and heat transfer, as well as improved mixing between the combustion air and the waste. The following investigation was done to determine if such improvements would aid in the thermal destruction of a liquid hazardous waste stream.

As stated previously, in order to excite large amplitude pulsations within a combustion chamber, the operating frequency of the pulse combustor must equal a frequency equal to one of the natural acoustic modes of the chamber. When this is achieved, resonance occurs within the system. The amplitude of the pulsations is maximized at the point of resonance.

Sonotech Inc. (Atlanta, Georgia) has developed a tunable pulse combustor which is capable of operating over a fairly wide frequency range. A tunable pulse combustor is not limited to one specific frequency value, and therefore can be utilized with various combustion chamber configurations. The tuning capability allows the burner to operate at a specific frequency that produces resonant pulsations in the chamber.

SECTION 2

EXPERIMENTAL

2.1 DESCRIPTION OF EQUIPMENT

2.1.1 <u>Research Furnace</u>

The experiments in this study were conducted using an 82 kW (280,000 Btu/hr) horizontal tunnel furnace. This unit (see Figure 1) consists of seven horizontal refractory-lined sections. The internal diameter of the furnace is 52.1 cm (20.5 inches) at the end near the flame and tapers to 26.7 cm (10.5 inches) midway through the horizontal chamber. The total length of the furnace is 3.96 m (13 feet). The unit is a versatile furnace in that it is equipped with numerous sampling ports. These ports are utilized for extractive sampling of combustion gases as well as pressure, temperature, and particulate measurements. Two quartz windows are available for flame visualization. The furnace is considered a pilot-scale model. However, critical parameters such as gas-phase residence time and temperature profiles are comparable to full-scale incineration facilities.

The exhaust gases from the furnace are first sent through a single-pass counter-flow heat exchanger. The heat exchanger cools the gases from approximately 648 to 371°C (1200 to 700°F). All continuous emission
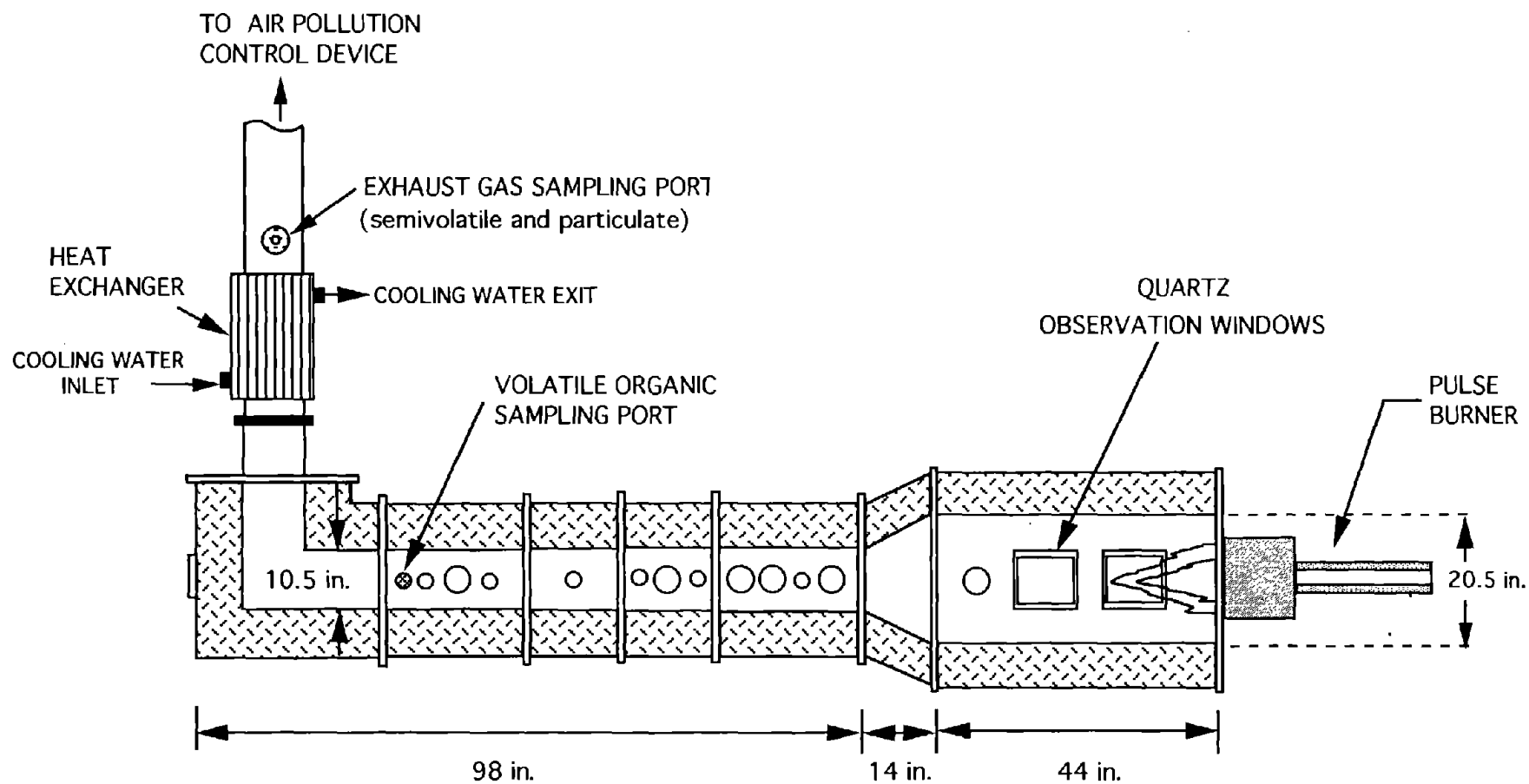
Figure 1: Horizontal Tunnel Furnace

monitoring is done immediately downstream of the heat exchanger. The monitoring consists of the on-line measurement of O_2 (Beckman model 755 paramagnetic), CO, CO_2 (Beckman model 864 infrared), and NO_x (Thermoelectron Series 10 Chemiluminescent). Following the heat exchanger and sampling ports, all combustion gases are sent to an air pollution control system (APCS). The APCS consists of an 879 kW (3×10^6 Btu/hr) boiler which functions as a secondary combustion device. Following this boiler, the gases are quenched and scrubbed of acid and particulate before being discharged into the environment. The APCS is oversized since it must handle effluents from other pilot-scale combustors in the laboratory.

2.1.2 Pulse Combustor

A pulse combustor was designed by Sonotech to operate at a maximum fuel input rate of 73 kW (250,000 Btu/hr). This is the maximum heat capacity of the EPA research furnace. The pulse combustor was welded in place at the large cylindrical end of the horizontal furnace (see Figure 2).

The fuel for the pulse burner was No. 2 fuel oil. The design of this pulse combustor features a natural-gas-fired fuel preheater unit. The purpose of this preheater unit is to vaporize the fuel oil prior to introduction into the main flame of the pulse burner. The fuel oil is pumped into the preheater unit through a spray nozzle. This causes the

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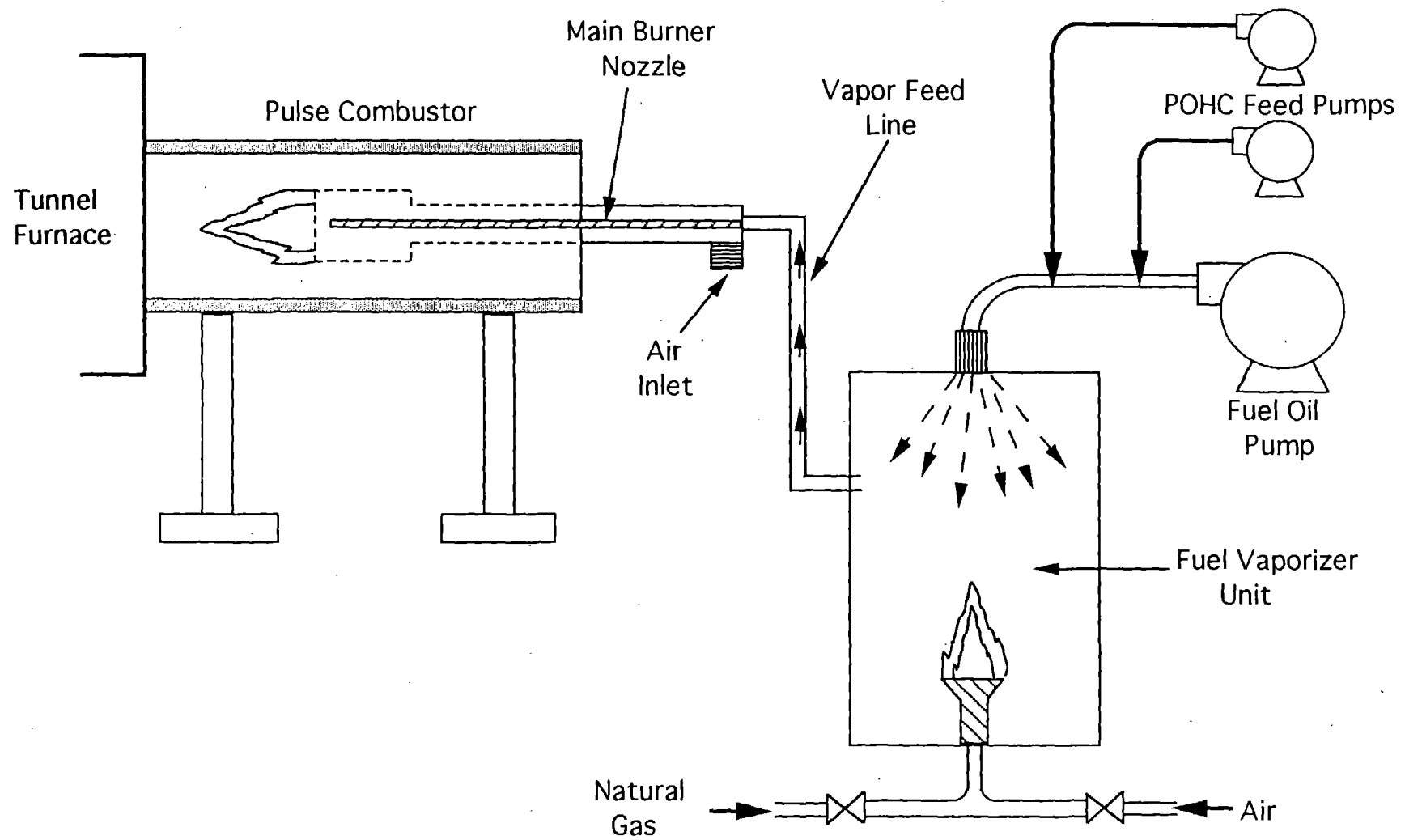
Figure 2: Liquid Injection Pulse Combustor

fuel oil flow to be atomized into tiny droplets and creates a conical spray zone above the natural gas flame. As this stream is heated, vaporization occurs and the gas stream continues to flow out of preheater unit and on through the primary combustion chamber of the pulse burner.

As stated previously, the goal of this study was to determine whether large amplitude pulsations would improve the thermal destruction capabilities of a furnace burning liquid hazardous waste. Therefore, in order to generate a liquid hazardous waste stream, surrogate waste compounds were added to the fuel oil feed stream. The surrogate wastes that were chosen for these experiments were two chlorinated solvents which were pumped directly into the fuel oil line upstream of the spray nozzle and preheater unit. The solvent streams were introduced far enough upstream of the preheater to allow for adequate mixing of the oil and solvents. High accuracy piston pumps were utilized for solvent pumping to provide precise mass flow rate measurements.

The remaining parts of the pulse burner are an air inlet port, a flame holder, and a refractory-lined combustion section. The vaporized fuel is sent to the main flame through another nozzle configuration which is located inside of this combustion section. The frequency of the pulse combustor is varied by changing the overall length of the combustion zone. This is accomplished by moving the location of the primary flame holder. The ability to change the combustor length provides for the unique tuning capabilities of the Sonotech pulse combustion system.

To find a point of resonance within the furnace, the output from a pressure transducer was monitored during the tuning process. This pressure transducer continuously monitors the pressure within the furnace. During tuning, the entire frequency range of the pulse burner is scanned. The location which yields the maximum output from the pressure transducer (measured in volts) represents a point of resonance. The nonpulsing mode of operation is set by tuning the pulse combustor to a point where the pulsation amplitude, as measured by the pressure transducer output, is at a minimum level.

In this investigation, the Sonotech pulse combustor was capable of operating over a frequency range of 50-500 cycles per second (Hz) within the furnace. The combustor produced acoustic pulsations with amplitudes as high as 160 decibels (dB) within this frequency range.

2.2 SURROGATE POHC SELECTION

To demonstrate compliance with the DRE standard, EPA regulations stipulate that incinerators must show adequate destruction of several selected organic compounds. The designated compounds are referred to as POHCs. These compounds are selected from a listing provided in the RCRA regulations (EPA, 1981).

Ideally, the chosen POHCs should have the overall highest resistance to incineration. If this is the case, a successful trial burn would demonstrate a thorough destruction of the most "difficult to burn"

compounds. However, several properties of thermal behavior should be considered when defining any relative factor that deals with incineration categories. Thus, different ranking schemes have been developed which list POHCs in order of incinerability.

The heat of combustion ranking system has been widely used in the past. This listing has been popular due to the fact that heat of combustion values can be readily obtained for a majority of POHCs. However, a newly developed ranking system based on a compound''s thermal stability at oxygen-starved conditions has been put together by the University of Dayton Research Institute. This ranking system was developed after it was demonstrated that listing compounds by the criteria of stability at starved-oxygen conditions correlated well with actual DRE performance data (Dellinger, et al., 1986).

The current incinerator permit guidance (EPA, 1989) suggests that POHCs should be chosen which rank high in thermal stability on both the heat of combustion and low oxygen stability listings. In adherence to this guidance, the two POHCs that were utilized for this pulse combustion study were carbon tetrachloride and chlorobenzene. Carbon tetrachloride is listed as the fourth highest thermally stable compound based on the heat of combustion ranking, while chlorobenzene is in the highest difficulty class based on the starved-oxygen stability criterion. These two compounds were also preferred as POHCs since they do not posses characteristics, such as reactivity or water solubility, which would cause difficulties in sampling and analysis.

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2.3 TESTS AND MEASUREMENTS

2.3.1 Test Design

Table 1 provides the experimental testing matrix that was utilized for this study. It is important to note that two separate runs were completed for each test condition. Two runs were required to directly compare the burner performance during pulsing and nonpulsing operations. Within each test condition, the only difference between pulsing and nonpulsing modes was in the tuning position of the primary flame. All other operational parameters, such as feed rates of air and fuel, remained constant. The firing rate of the pulse combustor was set at 58.6 kW (200,000 Btu/hr) for the entire study.

Three separate test conditions are shown in Table 1. Condition 1 represents the baseline condition in which pure fuel oil was fed to the combustor. No surrogate waste compounds were introduced for this baseline testing. The purpose of doing this series was to determine the tuning position that would produce large amplitude acoustic pulsations (resonance point), as well as to define the flame location that would generate pulsations at minimum amplitude. For baseline testing, the full-scale organic analysis (volatile and semivolatile) was done as well as particulate analysis. The organic analysis was done to determine the contribution that fuel oil would have on PIC formation. Particulate analysis was done to establish baseline particle emissions. No DRE

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Table 1

EXPERIMENTAL TEST MATRIX

Stack Gas Analyses

Test Conditions	Volatile Analysis	Semivolatile Analysis	Particulate Analysis	DRE Computation
Condition 1 Baseline (pulsing)	X	X	X	
Condition 1 Baseline (nonpulsing)	X	X	X	
Condition 2 POHC in Feed (pulsing)	X	X	X	X
Condition 2 POHC in Feed (nonpulsing)	X	X	X	X
Condition 3 Low Oxygen (pulsing)			X	
Condition 3 Low Oxygen (nonpulsing)			X	

Operating Parameters for all Tests:

- Pulse combustor firing rate = 200,000 Btu/hr

- Rainbow Tunnel Furnace Temperature = 1800 °F

- POHCs = Carbon tetrachloride and chlorobenzene

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computations were performed at Condition 1 since no POHCs were fed into the pulse combustor during this test series.

Test Condition 2 represents the two runs that were performed when burning fuel oil containing the two chlorinated POHCs at a concentration of 8.2 percent. As stated previously, the two chosen POHCs were carbon tetrachloride and chlorobenzene. By measuring the emissions of these compounds, DRE calculations were reported utilizing Condition 2 data.

For Conditions 1 and 2, the stoichiometric oxygen/fuel ratio (SR) was set at a value of 1.2. Thus, a 20 percent excess oxygen level was introduced for these conditions. The last experimental runs were performed at Condition 3. The major difference between Condition 3 and the other previous test runs was that oxygen levels were decreased significantly. The SR value for Condition 3 tests was set at approximately 1.03, which corresponds to an excess air level of only 3 percent. The purpose of running at the lower oxygen level was to determine if resonant pulsations could improve incineration performance under non-ideal combustion conditions. Due to operational problems of the burner, however, no volatile or semivolatile analyses were undertaken at Condition 3. The testing at this condition consisted only of particulate sizing analysis.

2.3.2 Determination of Volatile Organic Emissions

The method that was utilized for collection and analysis of volatile organic emissions in the stack gas was the Volatile Organic Sampling Train

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(VOST). This method is applicable to compounds with boiling points between 30 and 100°C (86 and 212°F). Since this technique is applicable for both of the POHCs in this study, the VOST data was utilized to calculate all DRE results. In addition, a chemical screening process was utilized to identify and quantify volatile PICs that were found by the VOST method.

Figure 3 provides a schematic of the components that make up the VOST. A glass-lined heated probe is utilized to withdraw the exhaust combustion gases from the pilot-scale furnace. The gas sample is then drawn through a chilled water condenser and then onto a sorbent cartridge. The sorbent, in this case, is Tenax® (Rohm and Haas) resin. The gas then flows through a condensate knockout flask and on through another condenser and Tenax®/carbon cartridge. A drying tube containing silica gel is the final in-line unit for water vapor entrapment. The VOST method specifies a gas sampling rate of 1 liter per minute and a total sampling time of 20 minutes. As shown in Figure 3, a dry gas meter is located in-line to ensure that adequate gas flow rates are maintained.

The volatile organic compounds that are collected on the sorbent tubes were analyzed using a purge-trap-desorb (P-T-D) method. Chemical analysis is done with a gas chromatograph/mass spectrometer (GC/MS). In this technique the sorbent traps are first thermally desorbed with nitrogen at elevated temperatures. The nitrogen purge gas is then sent through an analytical sorbent trap which contains resin, methyl silicone packing, silica gel, and charcoal sections in series. The analytical sorbent
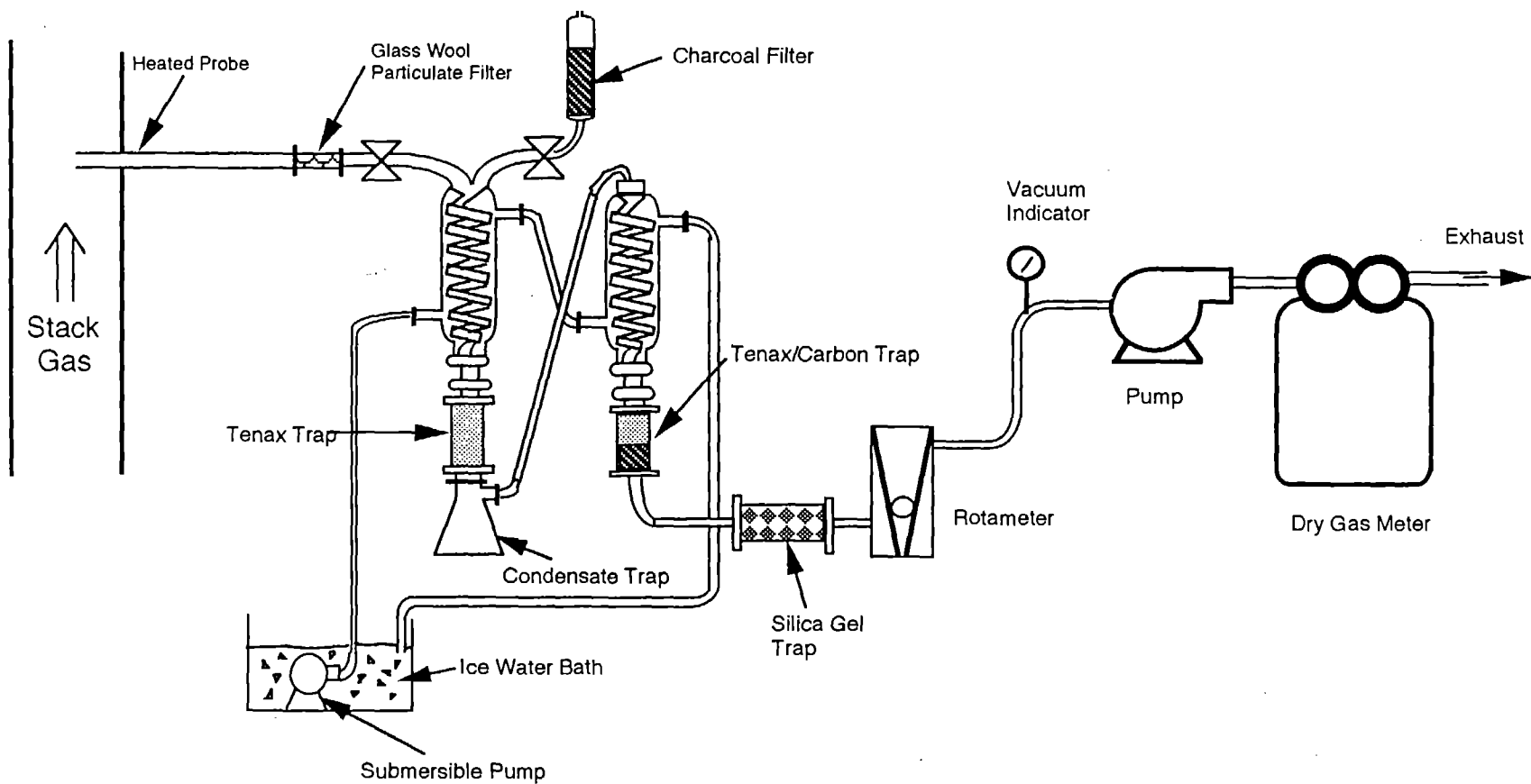
Figure 3: Volatile Organic Sampling Train (VOST)

trap is heated and purged with helium carrier gas which is immediately sent through the GC/MS for volatile organic compound identification.

2.3.3 Determination of Semivolatile Organic Emissions

The method that was utilized for collection and analysis of semivolatile organic emissions was the semi-VOST. This procedure is applicable for organic compounds with boiling points above 100°C (212°F). The moisture content of the stack gas was also determined with this testing method.

A schematic of the semi-VOST train is shown in Figure 4. Exhaust gases from the combustion process are withdrawn at an isokinetic sampling rate. The gas sample is first drawn through a heated sampling line and onto a filter. After filtering and passage through a condenser, the gas then flows through a cartridge that is filled with absorbent resin. The resin, in this case, is a porous polymeric material (Rohm and Haas XAD-2 or equivalent), which must be cooled to approximately 15°C (60°F) during sampling. The final component of the semi-VOST is a series of impingers which collect condensed moisture from the stack gas. As with the VOST, the semi-VOST is also equipped with a dry gas metering system. Semivolatile organic compounds are analyzed and quantified by first extracting the XAD-2 resin with methylene chloride. In this case, the Soxhlet extraction process is utilized. The methylene chloride extract is then concentrated and analyzed by GC/MS using a fused silica capillary GC column.
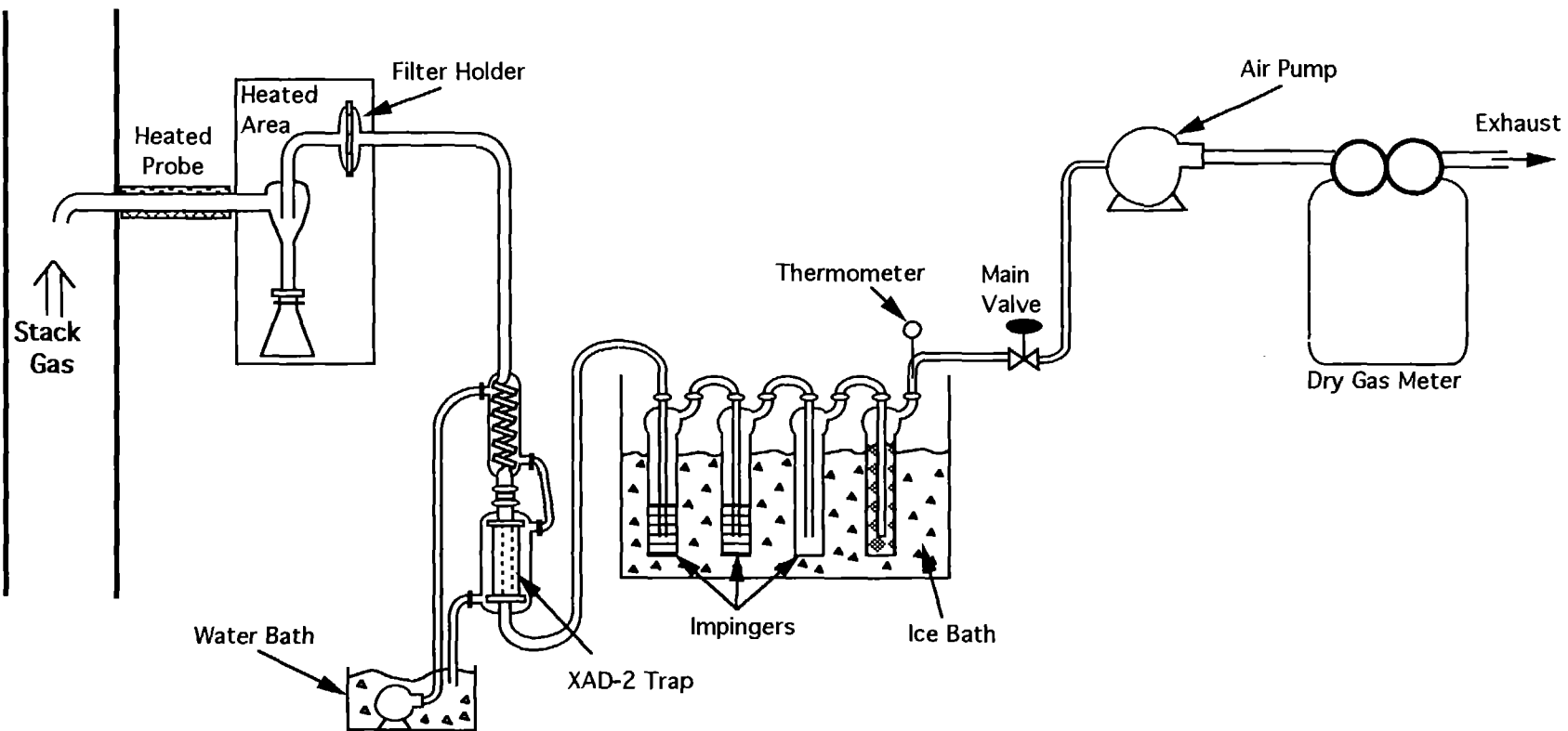
Figure 4: Semivolatile Organic Sampling Train (semi-VOST)

2.3.4 Determination of Particulate Emissions

Particulate matter in the stack gas was measured using two different sampling systems. The first system measures particulate emissions gravimetrically and yields a mass concentration value for particles greater than 1 μm in diameter. The filter in the semi-VOST (see Figure 4) was utilized for this method. The gas sample is drawn isokinetically and sent through a cyclone unit followed by a high efficiency fiber filter. The final particulate concentration value is determined by weighing the filter before and after testing as well as collecting and weighing the entrapped particles in the cyclone.

The second measurement system yields both a number concentration value and an overall size distribution for particulate matter in the stack gas. However, this method measures particles only less than 1 μm in diameter. The system consists of a Differential Mobility Particle Sizer (DMPS) in conjunction with a Condensation Particle Counter. For this analysis, the particles in the stack gas sample are charged and sent through a series of electric fields. The sizes of the particles are classified according to their ability to traverse through each field. As with the previous method, a gas sample is drawn from the exhaust stack at an isokinetic sampling rate.

SECTION 3

RESULTS

3.1 BURNER OPERATION

Before any experimental runs were undertaken, scoping exercises were completed while running the pulse combustor on pure fuel oil. During the scoping period, the pulse combustor was operated in a steady-state mode and the burner was fine tuned. No major operational upsets were encountered during this scoping period.

After the chlorinated POHCs were spiked into the fuel oil stream (Conditions 2 and 3), however, problems occurred with the vapor feed system. On several occasions runs had to be aborted due to clogging problems in the main nozzle of the pulse combustor. The clogging was due to soot being formed within the vaporizer and subsequently depositing on the walls of the nozzle. The soot was formed as a result of the fuel oil being subjected to the open flame in the vaporizer unit. The nozzle was taken out and cleaned as well as possible between tests. However, after each cleaning attempt, reattachment of the nozzle required a welding operation. The cleaning and welding operations eventually destroyed the integrity of the nozzle port. Thus, due to these operational problems, a limited number of experimental runs were able to be completed.

3.2 VOLATILE ORGANIC EMISSIONS

The results of the volatile compound screening procedure are summarized in Figures 5 and 6. Note that the GC/MS analytical procedure consisted of screening for 32 volatile compounds. The actual GC/MS output is found in Appendix A. The volatile compounds that are identified in Figures 5 and 6 are a small subset from the overall screening list which were present at levels above the Practical Quantitation Limit (PQL). In this case, the PQL for all volatile compounds is 1 ng/L. The quantities depicted in Figures 5 and 6 were determined by taking the mean value of three replicate runs from the VOST. Error bars are also provided to show one standard deviation.

For baseline testing when only fuel oil was burned, the first result to be noted is that several chlorinated compounds were detected in the exhaust gas stream. This result is not expected since No. 2 fuel oil should not contain any chlorine compounds. It is possible that small amounts of chlorinated contaminants were present in the fuel oil feed. However, the same chlorinated compounds that are shown in Figure 5a were also found on the field blanks from the VOST sampling (see Appendix A). In many cases, volatile concentrations from field blank analyses were of the same magnitude as the levels reported in the stack gas of the research furnace. This leads to the conclusion that chlorine was not a contaminant in the fuel. Instead, it is highly probable that airborne contamination in the area around the research furnace contributed to the occurrence of chlorinated compounds in the baseline results. Such outside
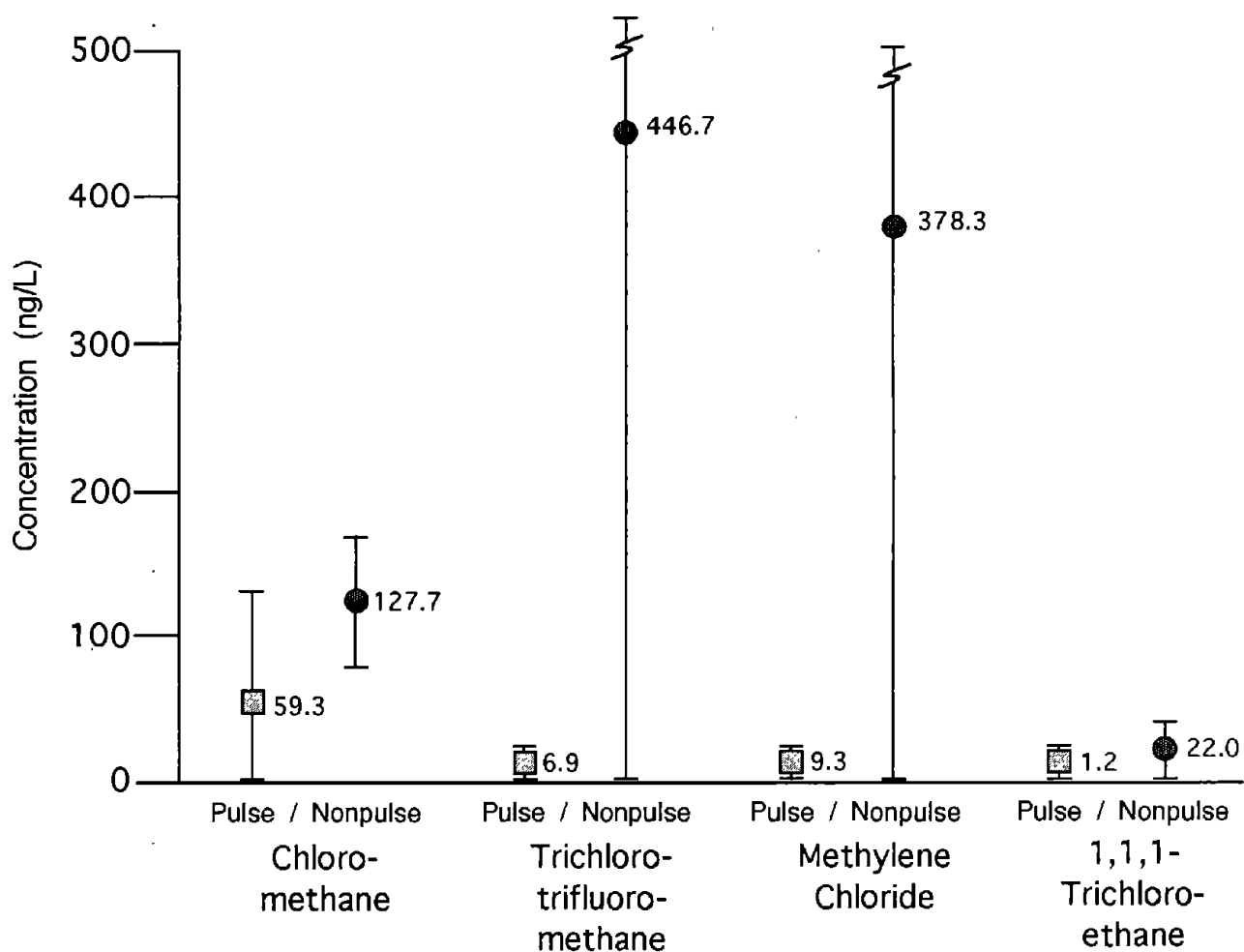
Figure 5a: Volatile Screening Results
Baseline Tests

(Error Bars Represent One Standard Deviation)

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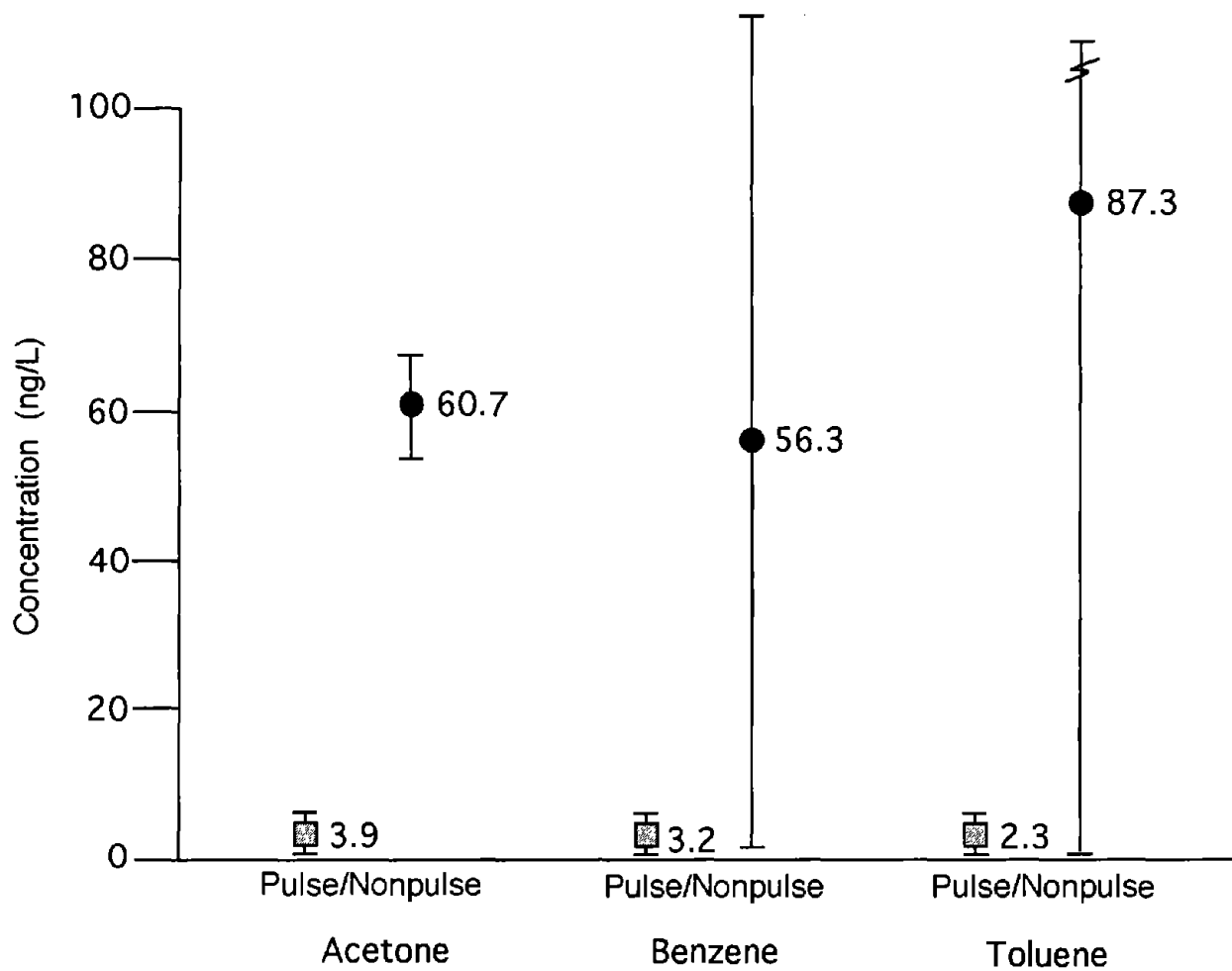
Figure 5b: Volatile Screening Results
              Baseline Tests (continued)

(Error Bars Represent One Standard Deviation)
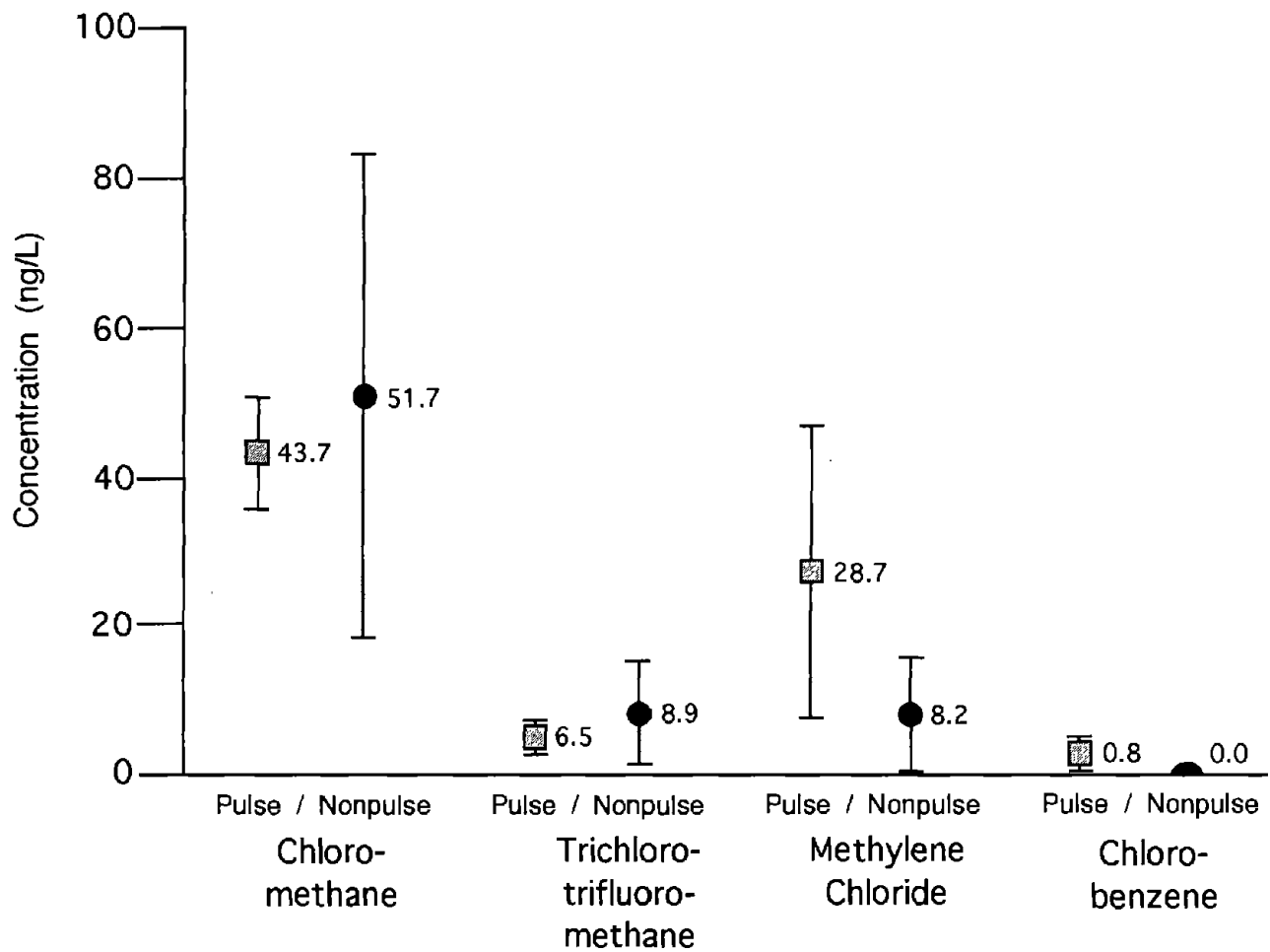
Figure 6a: Volatile Screening Results
POHC Tests

(Error Bars Represent One Standard Deviation)
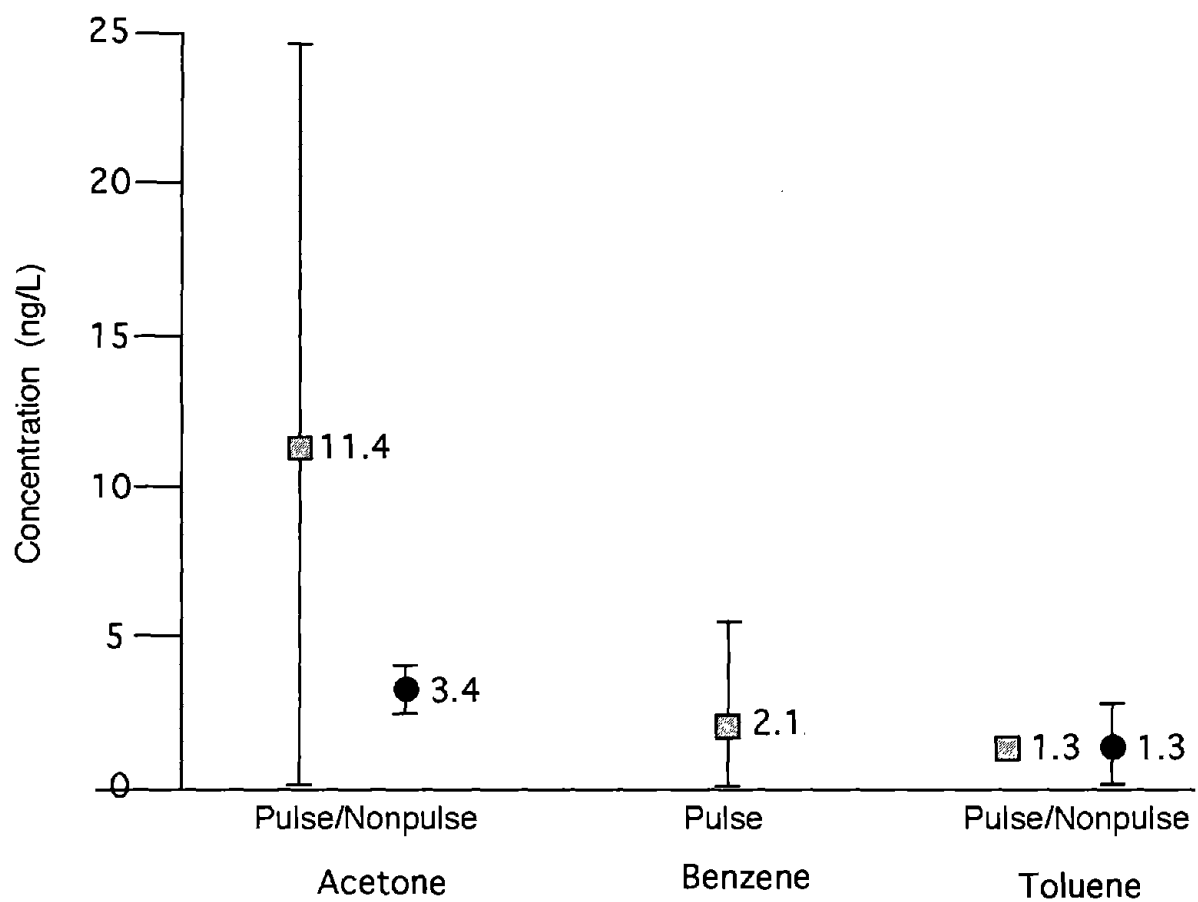
Figure 6b: Volatile Screening Results
POHC Tests (continued)

(Error Bars Represent One Standard Deviation)

contamination could also account for the large error bars noted in Figure 5a. Because the furnace was run at steady-state conditions, it is expected that variances between replicate runs should be reasonably small.

Detectable emissions not containing chlorine and fluorine are shown in Figure 5b. Of the compounds (acetone, benzene, and toluene) shown in Figure 5b, acetone and toluene were once again found in the field blanks. Therefore it cannot be stated with total certainty that these two compounds represent true PICs. While acetone and toluene may have been present in the stack gas, their reported low concentrations indicate that outside contamination factors must also be considered.

In summary, the volatile screening results from baseline testing do not provide substantial emission data to form conclusions on the effects of acoustic pulsations. In most cases, the noted concentration levels were quite small for both pulsing and nonpulsing conditions. Also, no consistent trends were seen between volatile concentration levels and the operational mode of the burner. Additionally, outside contamination may have had a significant impact on the these baseline screening analyses.

Figures 6a and 6b provide the volatile screening results for test runs where POHCs were added to the fuel oil feed stream (Condition 2). As with the baseline results, several of the compounds detected in Figure 6A were also present in the VOST field blanks and, therefore, outside contamination factors cannot be ignored. The volatile screening results from Condition 2 show that, in most cases, reported concentrations of volatile compounds

were small. In fact, many of the concentration values are relatively close to the detection limits of the GC/MS. Making a comparison between such low numbers does not form a good basis for conclusions on whether acoustic pulsations were having a significant effect on combustion emissions.

3.3 DRE RESULTS

Table 2 summarizes the results of DRE analysis. For carbon tetrachloride, no measurable emissions were found in any of the test series. Therefore, the minimum DRE value for this POHC is calculated by using the PQL of 1 ng/L as the stack gas concentration value. Substituting the appropriate feed and emission rates in the DRE equation yields a minimum DRE of 99.999967 percent (see Appendix B for all DRE calculations). An even greater destruction of carbon tetrachloride may have been achieved. However, the sensitivity of the testing method allows only for calculation of this minimum DRE level.

For chlorobenzene, the concentration in the stack gas was found to be below the PQL during a pulsing operation. Thus for the pulsing situation, DRE values are identical to the destruction levels reported for carbon tetrachloride. In the nonpulsing mode of operation, detectable levels of chlorobenzene were found. In this case, the highest detected concentration yields a DRE value of 99.999954 percent.

Table 2

DRE Results

Principal Organic Hazardous Constituent (POHC)

Operational Mode		Chlorobenzene	Carbon tetrachloride
	Pulse	> 99.999967 %	> 99.999967 %
	Nonpulse	99.999954 %	> 99.999967 %

Note: Minimum DRE values are calculated from the practical quantitation limit of the analysis method.

It is important to realize that, for all of the tests in this study, the VOST analysis shows a very high destruction of volatile organic compounds. All of the results show a destruction exceeding 99.9999 percent, which is two orders of magnitude greater than the 99.99 percent level mandated for hazardous waste incinerator permitting. When comparing the pulsing and nonpulsing operational modes of the pulse combustor, the results show that the volatile organic destruction was more than adequate in both cases.

3.4 SEMIVOLATILE ORGANIC EMISSIONS

The results from the semivolatile screening analysis are found in Appendix C. These results indicate that, for both the pulsing and nonpulsing modes of operation, semivolatile emissions were low. Note that field and method blanks were analyzed as part of the semivolatile analysis procedure. The phthalate compounds that were detected on the stack gas samples were also found to be present on the field blanks. As with the volatile analysis, the semivolatile screening results indicate that emissions were essentially below the sensitivity limit of the testing method.

3.5 PARTICULATE EMISSIONS

The results of the in-line filter particulate measurements are shown in Table 3. Actual measurements are found in Appendix D. The reported values for particulate emissions are in milligrams per dry standard cubic meter (mg/dscm). All of these results indicate that particulate emissions

were well below the EPA hazardous waste incinerator standard of 180 mg/dscm. It is important to realize that particle emissions are related to the type of feed that is introduced into the incinerator. The feed streams that were utilized in this study did not contain significant quantities of ash, nor did they contain appreciable amounts of soot producing compounds. Therefore, low particulate emissions would be expected during these testing periods. Measurements were still undertaken, however, to determine if acoustic pulsations would have a significant impact on the level of particulate emissions during steady-state operations.

The particulate size distribution results are shown in Figures 7 through 9. These results were obtained from the DMPS and apply for particle diameters smaller than 1 μm. Particulate loading and size concentration curves are provided for each test condition. The actual output from the DMPS equipment is provided in Appendix E. In these figures, the general shape of the particulate distribution curves did not change significantly when acoustic pulsations were introduced.

3.6 QUALITY ASSURANCE MEASUREMENTS

Data quality objectives set by the quality assurance project plan (QAP$_j$P) to meet EPA Category IV requirements were achieved. In this case the data were primarily qualitative, with the goal of showing relative differences between the fundamental parameters that were investigated. The data were more than adequate considering the scope and data requirements of this study.

Table 3

Particulate Emission Results

**Mass Concentration of
Collected Particulate (mg/dscm)**

		Baseline Tests	POHC Tests
Operational Mode	Pulse	23.89	49.17
	Nonpulse	2.04	45.05
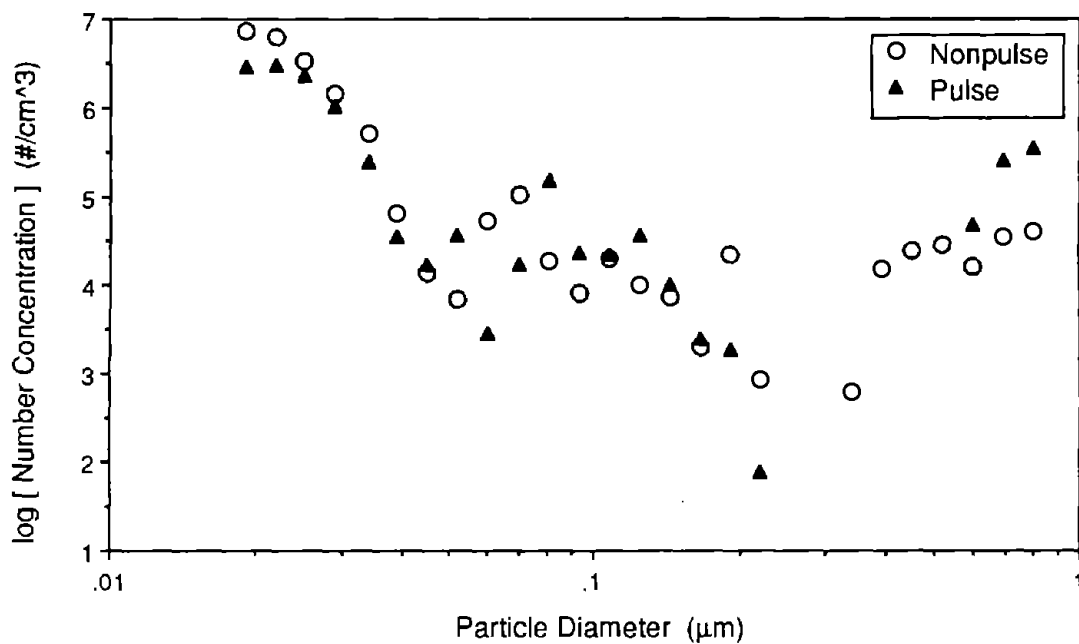
Figure 7a:
Particulate Loading Concentration Baseline Tests
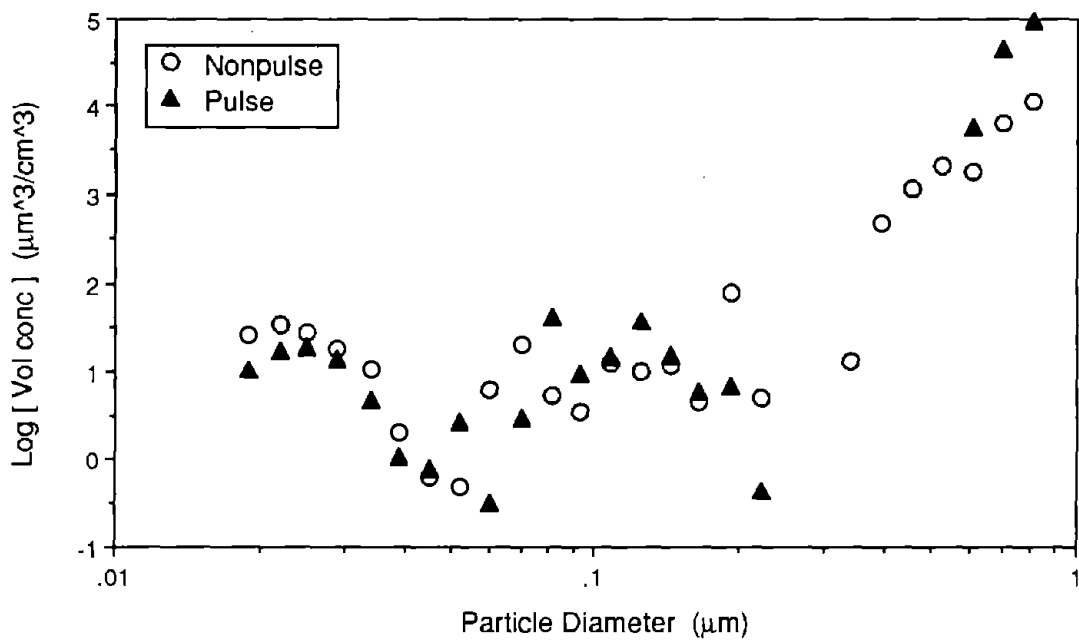
Figure 7b:
Particulate Size Concentration Baseline Tests

35
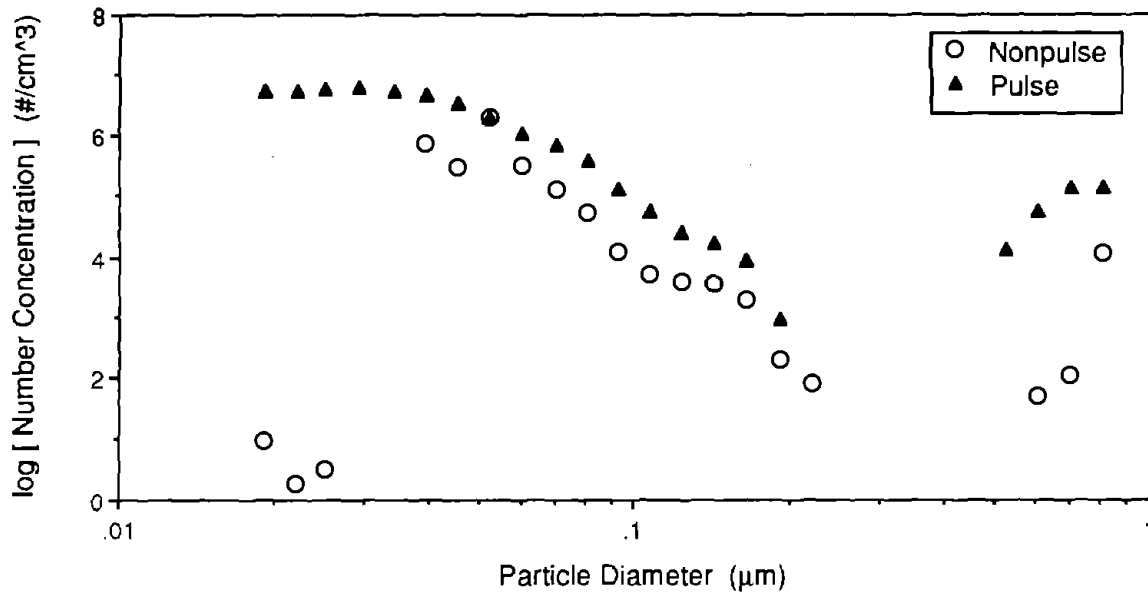
Figure 8a:

Particulate Loading Concentration POHC Tests
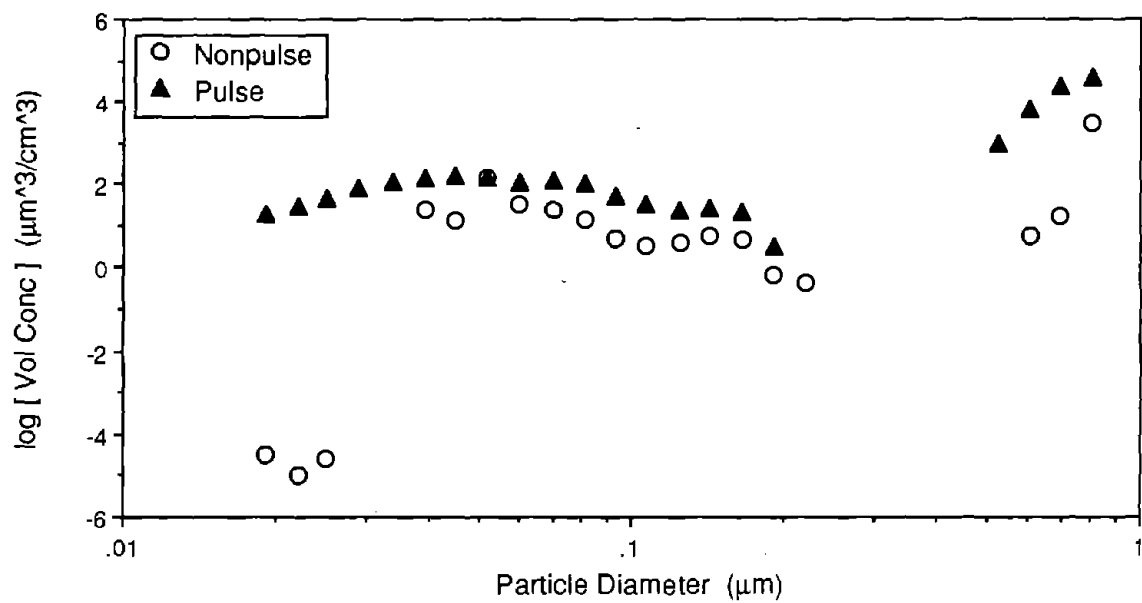
Figure 8b:

Particulate Size Concentration POHC Tests
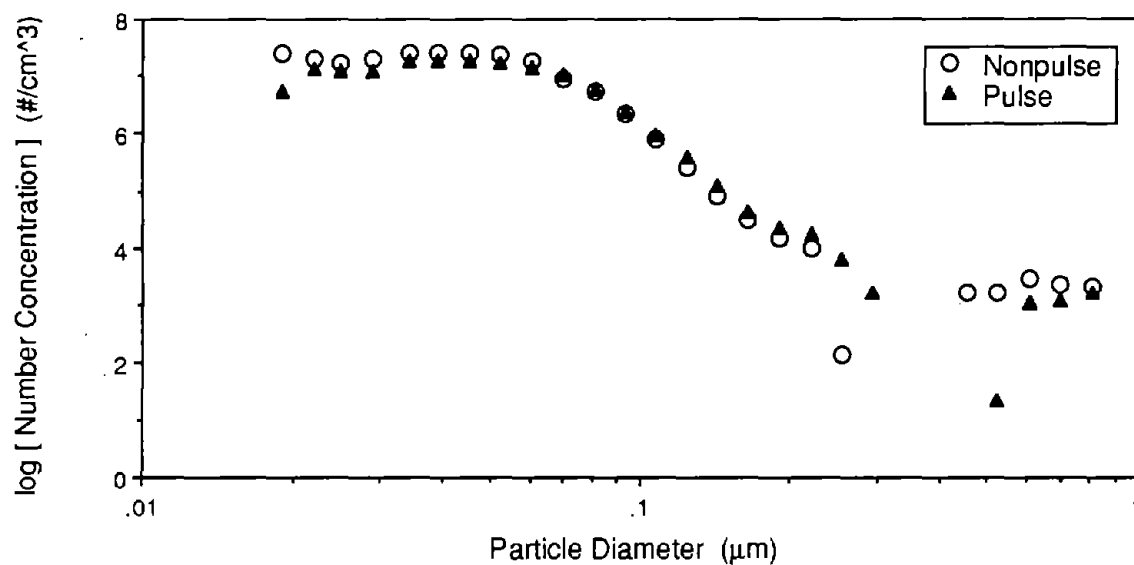
Figure 9a:

Particulate Loading Concentration Low Oxygen Tests
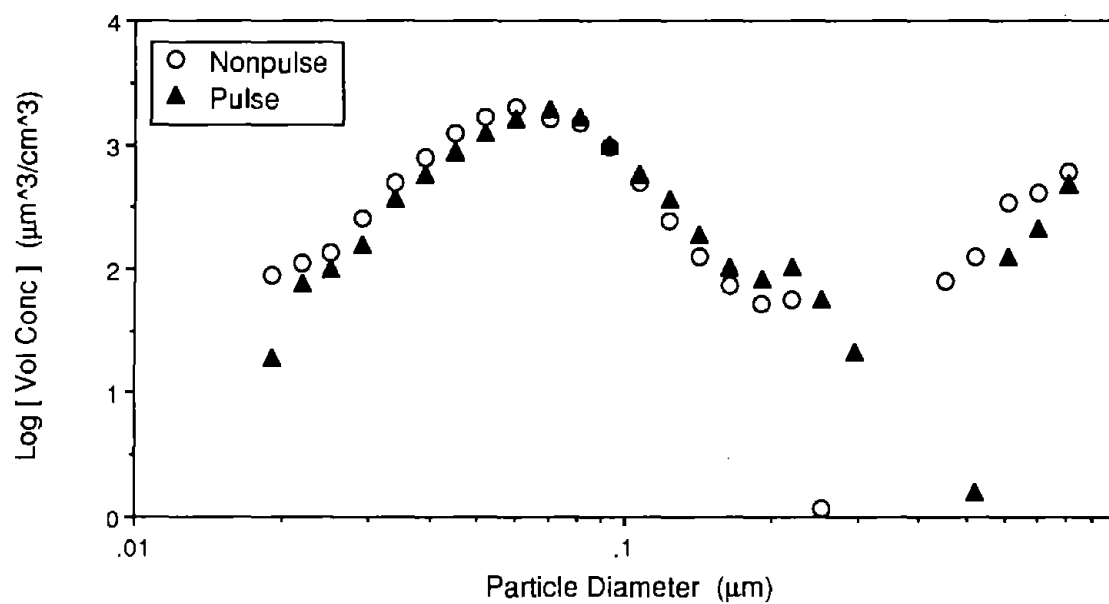
Figure 9b:

Particulate Size Concentration Low Oxygen Tests

SECTION 4

CONCLUSIONS

For this study, steady-state operation of the pulse combustor was not successful in isolating the effect of acoustic pulsations on combustion emissions. Under the steady-state conditions tested, the introduction of acoustic pulsations in the research furnace did not appear to affect emissions. The volatile screening results show that emissions were very low for all tests. At these low levels, outside contamination factors could not be discounted. The semivolatile and particulate results also indicate that acoustic pulsations did not impact these emissions. The DRE results for the two chlorinated POHCs show that this pulse combustor achieved greater than six-nines (99.9999 percent) destruction and removal. However, this same level of destruction was achieved during pulsing as well as nonpulsing operations.

A possible reason for the occurrence of low organic and particulate emissions at all test conditions may have been due to the utilization of a vaporized feed stream. For most liquid injection burners the liquid wastes are injected into the main burner, atomized into fine droplets, and burned in a suspension (Oppelt, 1987). This atomization is a critical parameter in achieving high destruction efficiency. Good atomization will produce tiny fuel droplets, thereby maximizing the available surface area for combustion.

For the pulse combustor in this study, the liquid fuel was atomized through a nozzle configuration. However, the atomization and subsequent vaporization of the droplets took place in a separate unit prior to introduction into the research furnace. Therefore, the effect of acoustic pulsations on the atomization of liquid feed could not be studied. It is highly probable that the fuel burned efficiently because critical elements, such as sizing of fuel droplets and fuel/droplet mixing, did not take place within the main flame of the burner.

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Appendix A

Volatile Organic Screening Results

Vost Results

Volatile Compound	Mean Conc. (ng/l)	Standard Deviation	Measured Concentrations (ng/l)		
Baseline Tests	------	------	-----------------		
Chloromethane - Pulse	59.3	78.55	12	150	16
Chloromethane - NonPulse	127.7	39.07	93	170	120
Bromomethane - Pulse	3.4	1.25	3.8	4.4	2
Trichlorofluoromethane - Pulse	6.9	2.19	9.4	6.2	5.2
Trichlorofluoromethane - NonPulse	446.7	570.12	190	50	1100
Acetone - Pulse	3.9	0.67	3.1	4.3	4.2
Acetone - NonPulse	60.7	7.23	56	57	69
Methylene Chloride - Pulse	9.3	2.19	11	10	6.8
Methylene Chloride - NonPulse	378.3	379.29	270	65	800
1,1,1 Trichloroethane - Pulse	1.2	2.02	3.5	0	0
1,1,1 Trichloroethane - NonPulse	22.0	20.30	0	26	40
Benzene - Pulse	3.2	2.65	6.2	2.4	1.1
Benzene - NonPulse	56.3	55.05	0	110	59
Toluene - Pulse	2.3	0.32	2.7	2.1	2.2
Toluene - NonPulse	87.3	89.37	45	27	190
POHC Tests					
Chloromethane - NonPulse	43.7	7.51	36	44	51
Chloromethane - Pulse	51.7	32.08	85	21	49
Bromomethane - Pulse	1.3	2.19	3.8	0	0
Trichlorotrifluoromethane -NonPulse	6.5	1.25	7.9	5.6	5.9
Trichlorotrifluoromethane -Pulse	8.9	5.78	14	10	2.6
Acetone - NonPulse	11.4	13.50	2.9	4.4	27
Acetone - Pulse	3.4	0.67	4.1	3.2	2.8
Methylene Chloride - NonPulse	28.7	20.21	52	17	17
Methylene Chloride - Pulse	8.2	9.38	19	2.1	3.5
1,1,1 Trichloroethane - Pulse	1.2	2.02	3.5	0	0
Toluene - NonPulse	1.3	0.10	1.2	1.3	1.4
Toluene -Pulse	1.3	1.42	2.8	0	1
Benzene - Pulse	2.1	3.58	6.2	0	0
Chlorobenzene - NonPulse	0.8	0.74	1.1	1.4	0
Chlorobenzene - Pulse	0.0	0.00	0	0	0

Field Blank Results	Measured Concentrations (ng/l)	
Field - Chloromethane	26	5.9
Field - Trichlorofluoromethane	43	28
Field - Acetone	48	4.5
Field - Methylene Chloride	130	100
Field - 111 Trichloromethane	73	
Field - Toluene	32	2.6

Pulsed Combustor VOST Volumes

Sample ID	Volume Sampled	Met Temp C	Corr Volume	
142/05	20.003	35	19.029	* Broken
90/06	20.000	35	19.026	
531/32	20.010	36	18.974	
07/08	19.992	36	18.957	
13/14	19.994	28	19.463	
270/16	19.998	33	19.148	
490/15	20.002	33	19.152	
10/11	20.000	31	19.276	
523/56	20.000	35	19.026	
532/42	20.017	37	18.919	
50/226	19.983	36	18.948	
497/767	20.000	39	18.782	
352/AP22	19.999	43	18.543	

PULSED COMBUSTOR
Acurex-RTP Laboratory Results
EPA Method 5040/8240 Compounds
Hewlett Packard 5890 GC / 5971 MSD; 30m x 0.53u DB-624 fused silica capillary;
Tekmar LSC-2000 w/Carbotrap/Carbosieve SIII.
PQL = Practical Quantitation Limit;
N/D = Not Detected
J = Detected @< PQL
N/A = Not Applicable

Sample Type	VOST	VOST	VOST	VOST	
Master Index	NA	NA	NA	NA	
Sample ID	10,11	523,56	532,42	142	
Sample Collected (Liters)	19.276	19.026	18.919	19.029	
Collection Date	07/15/92	07/15/92	07/15/92	07/13/92	PQL
Analysis Date	8/10/92	8/10/92	8/11/92	8/11/92	ng/xL
	ng/L	ng/L	ng/L	ng/L	

Chloromethane	85	21	49	ND	20
Vinyl chloride	ND	ND	ND	ND	20
Bromomethane	3.8	ND	ND	ND	20
Chloroethane	ND	ND	ND	ND	20
Trichlorofluoromethane	14	10	2.6	ND	20
1,1-Dichloroethene	ND	ND	ND	ND	20
Acetone	4.1	3.2	2.8	2.5	20
Methylene chloride	19	2.1	3.5	ND	20
Trans-1,2-dichloroethene	ND	ND	ND	ND	20
1,1-Dichloroethane	ND	ND	ND	ND	20
Chloroform	ND	ND	ND	ND	20
1,1,1-Trichloroethane	3.5	ND	ND	ND	20
Carbon tetrachloride	ND	ND	ND	ND	20
1,2-Dichloroethane	ND	ND	ND	ND	20
Benzene	6.2	ND	ND	ND	20
Trichloroethene	ND	ND	ND	ND	20
1,2-Dichloropropane	ND	ND	ND	ND	20
Bromodichloromethane	ND	ND	ND	ND	20
cis-1,3-Dichloropropene	ND	ND	ND	ND	20
Toluene	2.8	ND	1.0	1.3	20
trans-1,3-Dichloropropene	ND	ND	ND	ND	20
1,1,2-Trichloroethane	ND	ND	ND	ND	20
Tetrachloroethene	ND	ND	ND	ND	20
Dibromochloromethane	ND	ND	ND	ND	20
Chlorobenzene	ND	ND	ND	ND	20
Ethyl benzene	1.2	ND	ND	ND	20
Total Xylenes	ND	ND	ND	ND	20
Bromoform	ND	ND	ND	ND	20
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	20
1,3-Dichlorobenzene	ND	ND	ND	ND	20
1,4-Dichlorobenzene	ND	ND	ND	ND	20
1,2-Dichlorobenzene	ND	ND	ND	ND	20

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. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Sample ID Number              10,11      523,56     532,42      142
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Surrogate Compounds Recovery    %          %          %          %

d6-Benzene                      92         88        100         63
1,2-Dichloroethane d-4         125        105        125        104
Toluene d-8                    125        103        120        102
Bromofluorobenzene              99         79         88         72
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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Analyst _Mitchell Powell_ Laboratory Manager _Alston Sykes_ Date _10-13-92_
Lotus 1-2-3 File Name:pulsed2

PULSED COMBUSTOR
Acurex-RTP Laboratory Results
EPA Method 5040/8240 Compounds
Hewlett Packard 5890 GC / 5971 MSD; 30m x 0.53u DB-624 fused silica capillary;
Tekmar LSC-2000 w/Carbotrap/Carbosieve SIII.
PQL = Practical Quantitation Limit;
N/D = Not Detected
J = Detected @< PQL
N/A = Not Applicable

Sample Type	VOST	VOST	VOST	VOST	
Master Index	NA	NA	NA	NA	
Sample ID	201/12	13,14	207,16	490,15	
Sample Collected (Liters)	0	19.463	19.148	19.152	
Collection Date	07/15/92	07/15/92	07/15/92	07/15/92	PQL..
Analysis Date	8/10/92	8/10/92	8/10/92	8/10/92	ng/xL
	ng	ng/L	ng/L	ng/L	
Chloromethane	26	4.8	8.7	6.4	20
Vinyl chloride	ND	ND	ND	ND	20
Bromomethane	ND	ND	ND	ND	20
Chloroethane	ND	ND	ND	ND	20
Trichlorofluoromethane	43	10	2.6	58	20
1,1-Dichloroethene	ND	ND	ND	ND	20
Acetone	48	2.9	3.0	3.6	20
Methylene chloride	130	14	3.4	42	20
Trans-1,2-dichloroethene	ND	ND	ND	ND	20
1,1-Dichloroethane	ND	ND	ND	ND	20
Chloroform	ND	ND	ND	ND	20
1,1,1-Trichloroethane	73	ND	1.4	2.1	20
Carbon tetrachloride	ND	ND	ND	ND	20
1,2-Dichloroethane	ND	ND	ND	ND	20
Benzene	ND	ND	5.6	3.1	20
Trichloroethene	ND	ND	ND	ND	20
1,2-Dichloropropane	ND	ND	ND	ND	20
Bromodichloromethane	ND	ND	ND	ND	20
cis-1,3-Dichloropropene	ND	ND	ND	ND	20
Toluene	32	2.3	1.4	10	20
trans-1,3-Dichloropropene	ND	ND	ND	ND	20
1,1,2-Trichloroethane	ND	ND	ND	ND	20
Tetrachloroethene	ND	ND	ND	ND	20
Dibromochloromethane	ND	ND	ND	ND	20
Chlorobenzene	ND	ND	ND	ND	20
Ethyl benzene	ND	ND	ND	ND	20
Total Xylenes	ND	ND	ND	ND	20
Bromoform	ND	ND	ND	ND	20
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	20
1,3-Dichlorobenzene	ND	ND	ND	ND	20
1,4-Dichlorobenzene	ND	ND	ND	ND	20
1,2-Dichlorobenzene	ND	ND	ND	ND	20

Sample ID Number	201/12	13,14	270,16	490,15
Surrogate Compounds Recovery	%	%	%	%
d6-Benzene	98	89	102	108
1,2-Dichloroethane d-4	121	97	119	129
Toluene d-8	115	93	120	127
Bromofluorobenzene	99	80	98	102

Analyst _Mitchell Bowell_ Laboratory Manager _Milton Sykes_ Date _10-14-92_
Lotus 1-2-3 File Name:pulsed1

PULSED COMBUSTOR

Acurex-RTP Laboratory Results

EPA Method 5040/8240 Compounds

Hewlett Packard 5890 GC / 5971 MSD; 30m x 0.53u DB-624 fused silica capillary;

Tekmar LSC-2000 w/Carbotrap/Carbosieve SIII.

PQL = Practical Quantitation Limit;

N/D = Not Detected

J = Detected @< PQL.

N/A = Not Applicable

Sample Type	VOST	VOST	VOST	VOST	
Master Index	NA	NA	NA	NA	
Sample ID	90,06	531,32	07,08	50,226	
Sample Collected	19.026	18.974	18.957	18.948	
Collection Date	07/13/92	07/13/92	07/13/92	07/22/92	PQL
Analysis Date	8/11/92	8/11/92	8/11/92	8/11/92	ng/xL
	ng/L	ng/L	ng/L	ng/L	
Chloromethane	12	150	16	51	20
Vinyl chloride	ND	ND	ND	ND	20
Bromomethane	3.8	4.4	2.0	ND	20
Chloroethane	ND	ND	ND	ND	20
Trichlorofluoromethane	9.4	6.2	5.2	5.9	20
1,1-Dichloroethene	ND	ND	ND	ND	20
Acetone	3.1	4.3	4.2	27	20
Methylene chloride	11	10	6.8	17	20
Trans-1,2-dichloroethene	ND	ND	ND	ND	20
1,1-Dichloroethane	ND	ND	ND	ND	20
Chloroform	ND	ND	ND	ND	20
1,1,1-Trichloroethane	3.5	ND	ND	ND	20
Carbon tetrachloride	ND	ND	ND	ND	20
1,2-Dichloroethane	ND	ND	ND	ND	20
Benzene	6.2	2.4	1.1	ND	20
Trichloroethene	ND	ND	ND	ND	20
1,2-Dichloropropane	ND	ND	ND	ND	20
Bromodichloromethane	ND	ND	ND	ND	20
cis-1,3-Dichloropropene	ND	ND	ND	ND	20
Toluene	2.7	2.1	2.2	1.4	20
trans-1,3-Dichloropropene	ND	ND	ND	ND	20
1,1,2-Trichloroethane	ND	ND	ND	ND	20
Tetrachloroethene	ND	ND	ND	ND	20
Dibromochloromethane	ND	ND	ND	ND	20
Chlorobenzene	ND	ND	ND	ND	20
Ethyl benzene	ND	ND	ND	ND	20
Total Xylenes	ND	ND	ND	ND	20
Bromoform	ND	ND	ND	ND	20
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	20
1,3-Dichlorobenzene	ND	ND	ND	ND	20
1,4-Dichlorobenzene	ND	ND	ND	ND	20
1,2-Dichlorobenzene	ND	ND	ND	ND	20

Sample ID Number	90,06	531,32	07,08	50,226
Surrogate Compounds Recovery	%	%	%	%
d6-Benzene	96	92	105	101
1,2-Dichloroethane d-4	125	107	127	126
Toluene d-8	121	103	127	123
Bromofluorobenzene	88	75	91	86

Analyst *Mitchell Powell* Laboratory Manager *Alston Sykes* Date 10-13-92
Lotus 1-2-3 File Name:pulsed3

PULSED COMBUSTOR
Acurex-RTP Laboratory Results
EPA Method 5040/8240 Compounds
Hewlett Packard 5890 GC / 5971 MSD; 30m x 0.53u DB-624 fused silica capillary;
Tekmar LSC-2000 w/Carbotrap/Carbosieve SIII.
PQL = Practical Quantitation Limit;
N/D = Not Detected
J = Detected @< PQL
N/A = Not Applicable

Sample Type	VOST	VOST	VOST	
Master Index	NA	NA	NA	
Sample ID	352,AP22	497,767	463,64	
Sample Collected (Liters)	18.543	18.782	0	
Collection Date	07/22/92	07/22/92	07/22/92	PQL.
Analysis Date	8/16/92	8/16/92	8/16/92	ng/xL
	ng/L	ng/L	ng/L	
Chloromethane	36	44	5.9	20
Vinyl chloride	ND	ND	ND	20
Bromomethane	ND	ND	ND	20
Chloroethane	ND	ND	ND	20
Trichlorofluoromethane	7.9	5.6	28	20
1,1-Dichloroethene	ND	ND	ND	20
Acetone	2.9	4.4	4.5	20
Methylene chloride	52	17	100	20
Trans-1,2-dichloroethene	ND	ND	ND	20
1,1-Dichloroethane	ND	ND	ND	20
Chloroform	ND	ND	ND	20
1,1,1-Trichloroethane	ND	ND	ND	20
Carbon tetrachloride	ND	ND	ND	20
1,2-Dichloroethane	ND	ND	ND	20
Benzene	ND	ND	ND	20
Trichloroethene	ND	ND	ND	20
1,2-Dichloropropane	ND	ND	ND	20
Bromodichloromethane	ND	ND	ND	20
cis-1,3-Dichloropropene	ND	ND	ND	20
Toluene	1.2	1.3	2.6	20
trans-1,3-Dichloropropene	ND	ND	ND	20
1,1,2-Trichloroethane	ND	ND	ND	20
Tetrachloroethene	ND	ND	ND	20
Dibromochloromethane	ND	ND	ND	20
Chlorobenzene	1.1	1.4	ND	20
Ethyl benzene	ND	ND	ND	20
Total Xylenes	ND	ND	ND	20
Bromoform	ND	ND	ND	20
1,1,2,2-Tetrachloroethane	ND	ND	ND	20
1,3-Dichlorobenzene	ND	ND	ND	20
1,4-Dichlorobenzene	ND	ND	ND	20
1,2-Dichlorobenzene	ND	ND	ND	20

```
Sample ID Number                     352,AP22    497,767    463,64
```

Surrogate Compounds Recovery	%	%	%
d6·Benzene	102	107	99
1,2-Dichloroethane d-4	130	130	110
Toluene d-8	124	121	105
Bromofluorobenzene	86	88	76

Analyst *Mitchell Boyd* Laboratory Manager *Alston Sykes* Date 10-13-92
Lotus 1-2-3 File Name:pulsed4

Operator ID: M HOWELL   Date Acquired: 10 Aug 92 10:03 pm
Data File: C:\CHEMPC\DATA\HPA1149.D
Name: VOST,#270,#16,PULSED COMBUSTER ,L,AIR,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

QUANT REPORT
Operator ID: M HOWELL   Date Acquired: 10 Aug 92   9:21 pm
Data File: C:\CHEMPC\DATA\HPA1148.D
Name: VOST,#13,#14,PULSED COMBUSTER ,L,AIR,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 10 Aug 92   7:44 pm
Data File: C:\CHEMPC\DATA\HPA1147.D
Name: VOST,#201,#12,FIELD BLANK ,L,AIR,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 10 Aug 92 10:45 pm
Data File: C:\CHEMPC\DATA\HPA1150.D
Name: VOST,#490,#15,PULSED COMBUSTER,L,AIR,,BFB,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 10 Aug 92 11:42 pm
Data File: C:\CHEMPC\DATA\HPA1151.D
Name: VOST,#10,#11,PULSED COMBUSTER,L,AIR,,BFB,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

TIC: HPA1151.D

Operator ID: M HOWELL   Date Acquired: 11 Aug 92   0:19 am
Data File: C:\CHEMPC\DATA\HPA1152.D
Name: VOST,#523,#56,PULSED COMBUSTER,L,AIR,,BFB,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 11 Aug 92   7:01 pm
Data File: C:\CHEMPC\DATA\HPA1156.D
Name: VOST,#532,#42,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 11 Aug 92   7:38 pm
Data File: C:\CHEMPC\DATA\HPA1157.D
Name: VOST,#142,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 11 Aug 92   8:34 pm
Data File: C:\CHEMPC\DATA\HPA1158.D
Name: VOST,#90,#06,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Operator ID: M HOWELL   Date Acquired: 11 Aug 92   9:11 pm
Data File: C:\CHEMPC\DATA\HPA1159.D
Name: VOST,#531,#32,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992
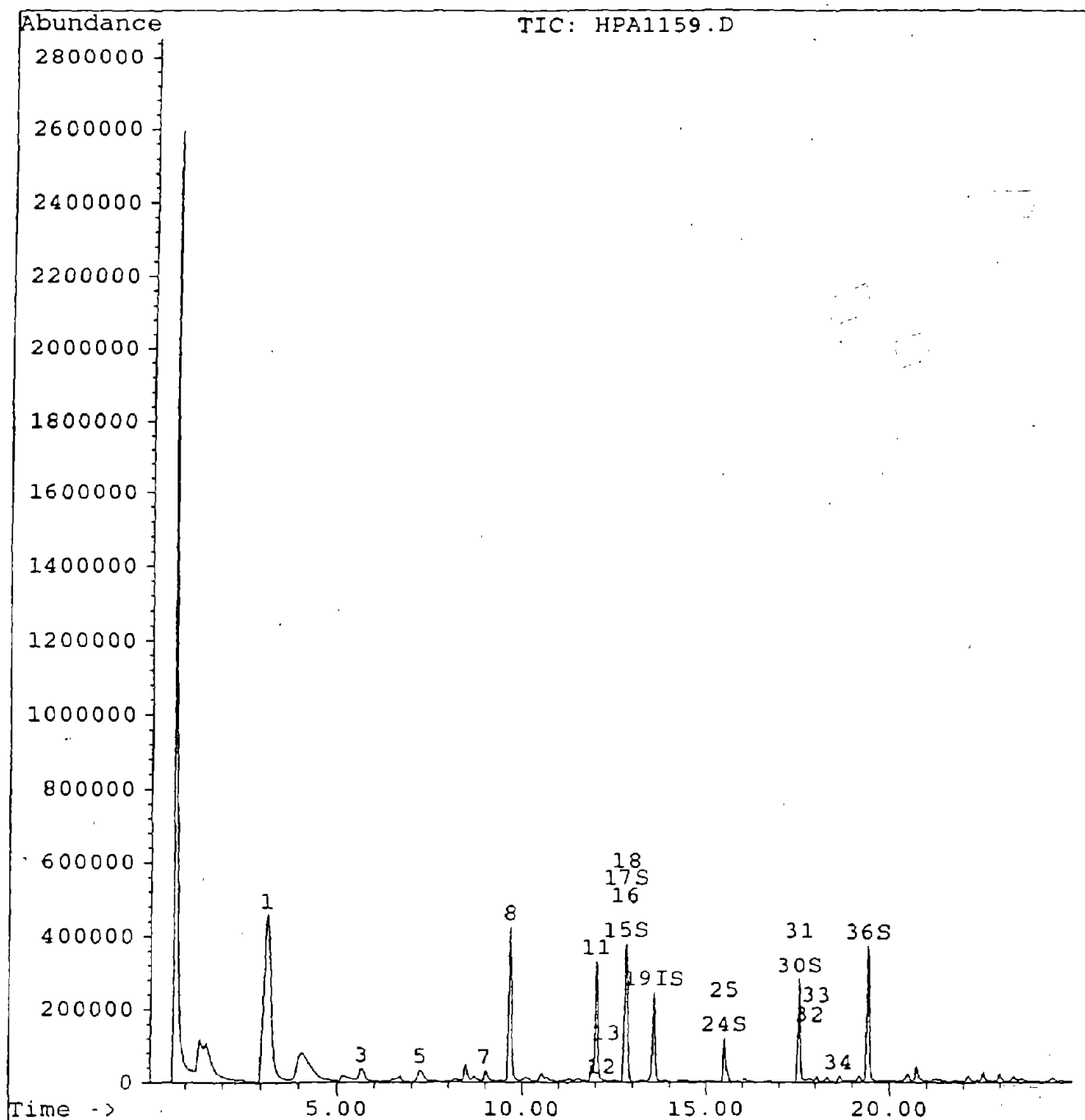
Operator ID: M HOWELL   Date Acquired: 11 Aug 92   9:49 pm
Data File: C:\CHEMPC\DATA\HPA1160.D
Name: VOST,#07,#08,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992
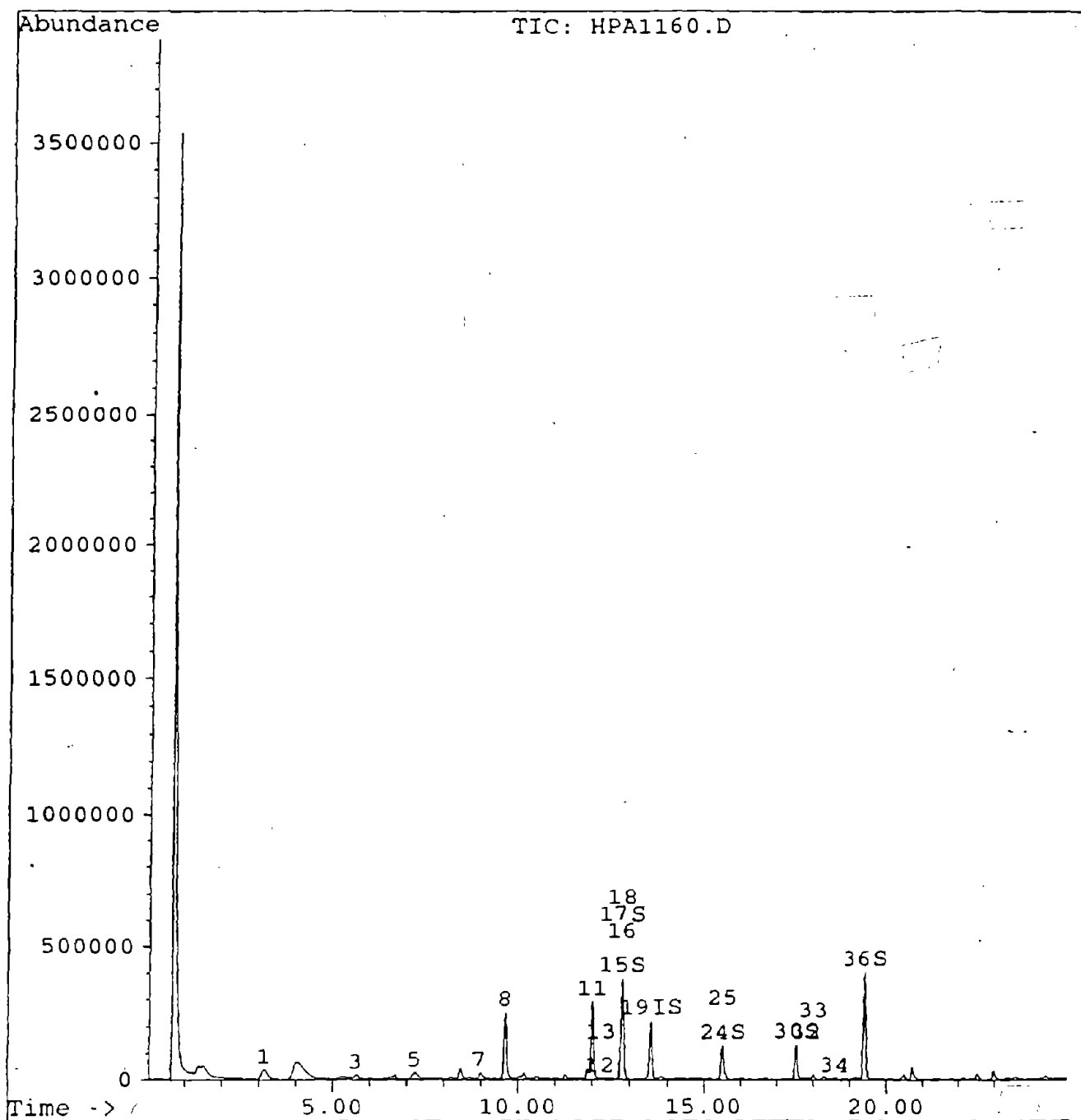
Operator ID: M HOWELL   Date Acquired: 11 Aug 92   10:27 pm
Data File: C:\CHEMPC\DATA\HPA1161.D
Name: VOST,#50,#226,PULSED COMBUSTER,L,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

Abundance   TIC: HPA1161.D
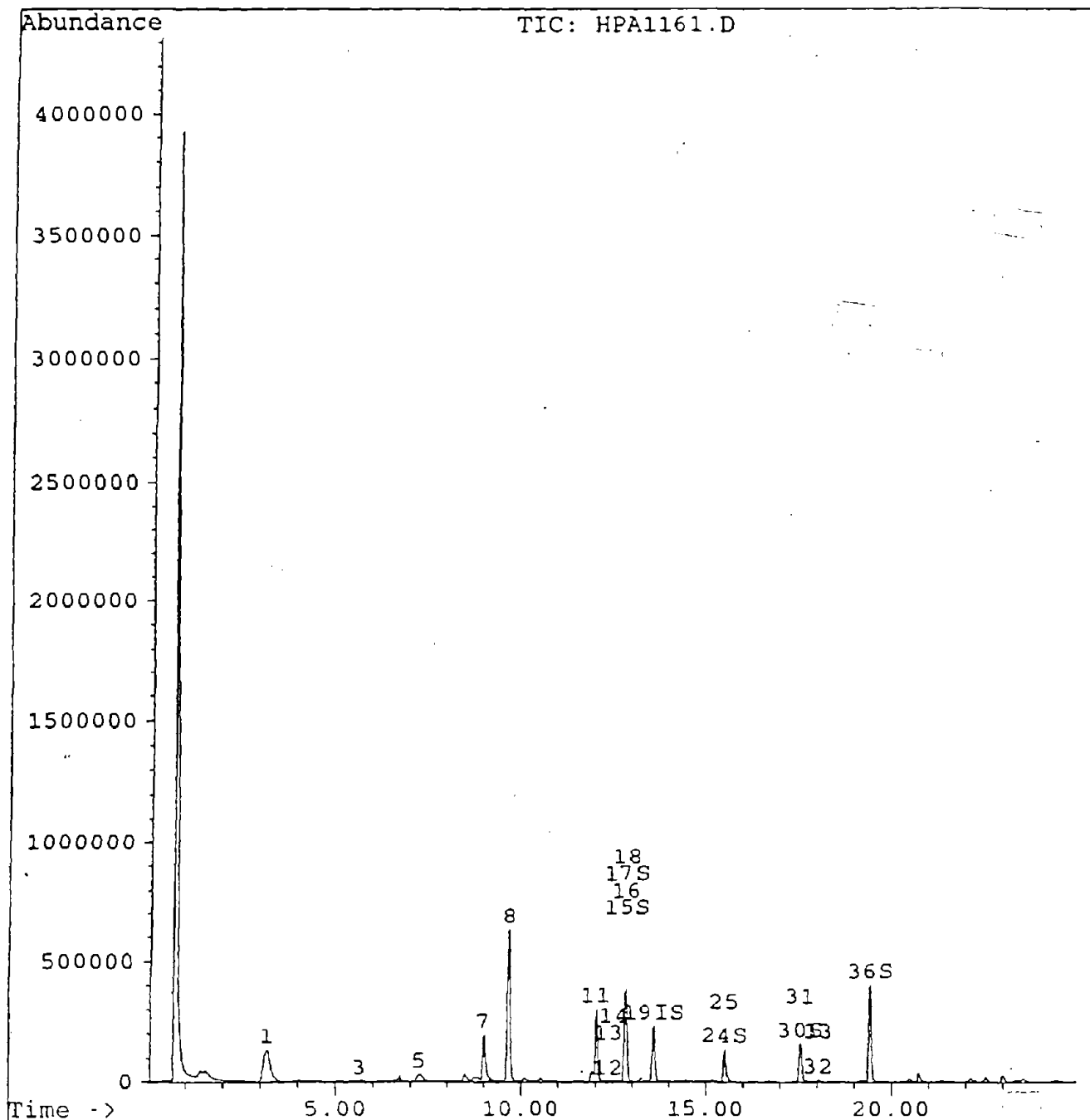
Operator ID: M HOWELL   Date Acquired: 16 Aug 92   9:13 pm
Data File: C:\CHEMPC\DATA\HPA1165.D
Name: VOST,#352,#AP22,PULSED COMBUSTER,L,AIR,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992
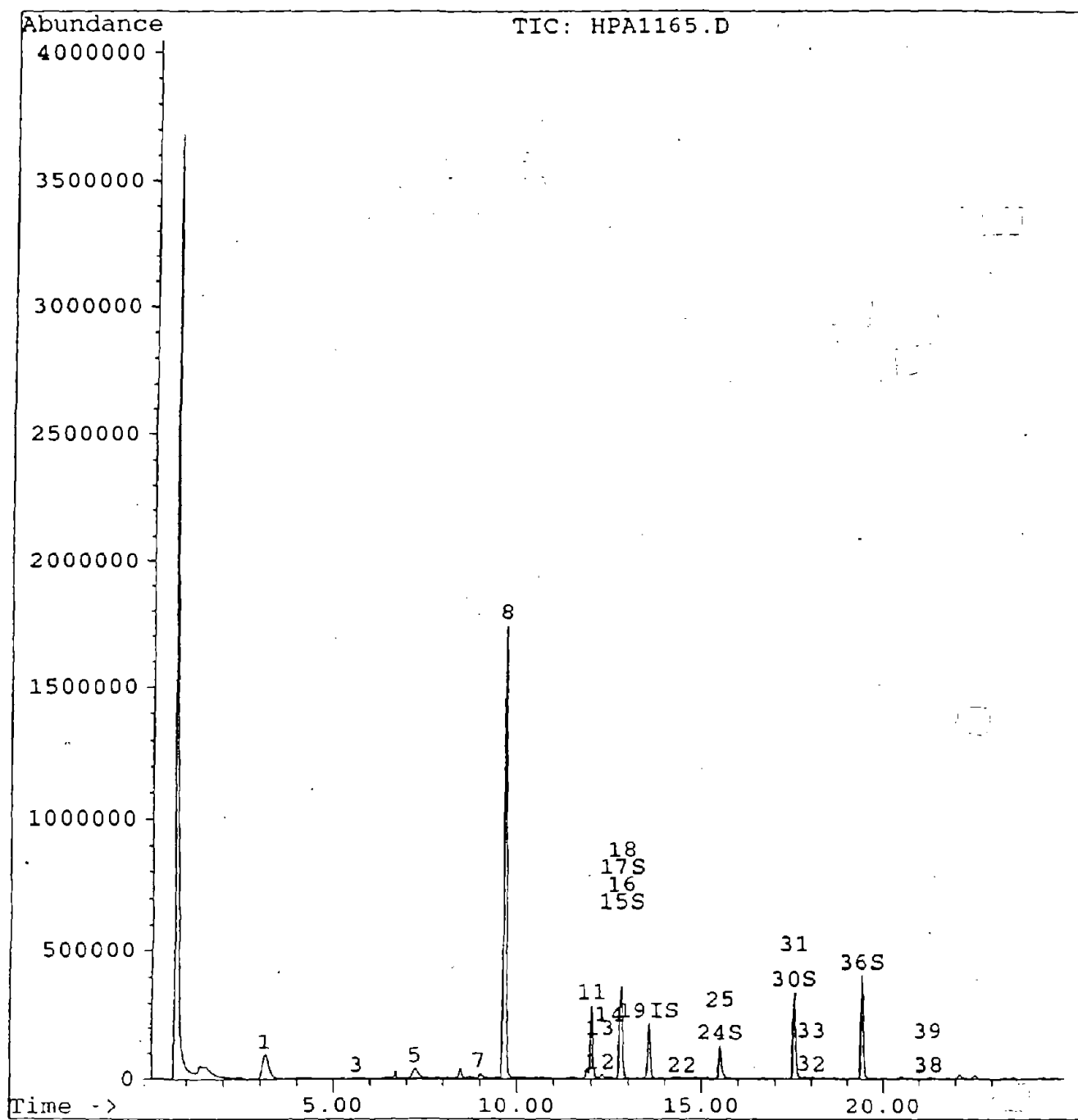
Operator ID: M HOWELL   Date Acquired: 16 Aug 92   9:57 pm
Data File: C:\CHEMPC\DATA\HPA1166.D
Name: VOST,#497,#767,PULSED COMBUSTER,L,AIR,EPA,
Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992
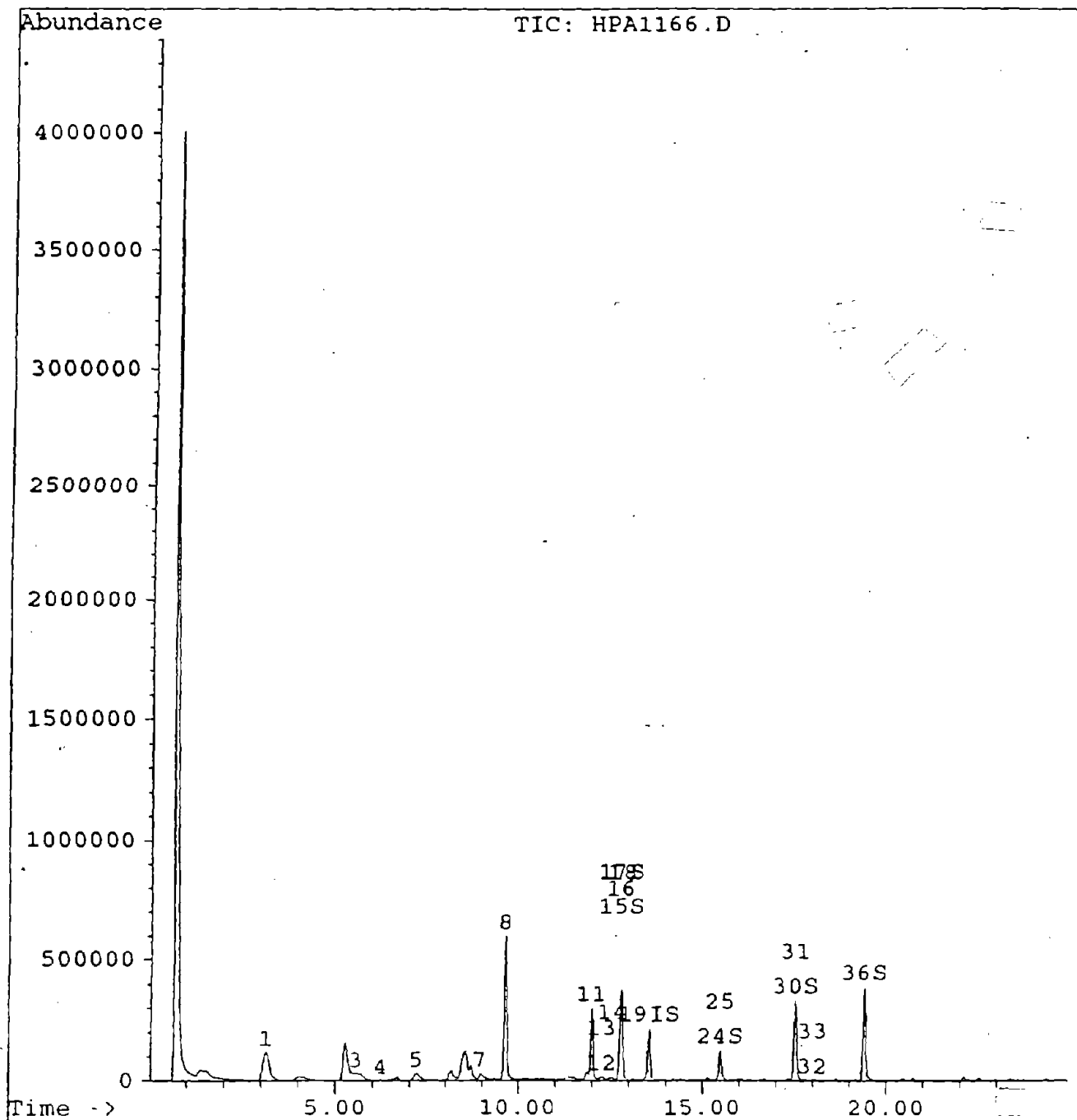
Operator ID: M HOWELL   Date Acquired: 16 Aug 92 11:02 pm
Data File: C:\CHEMPC\DATA\HPA1167.D
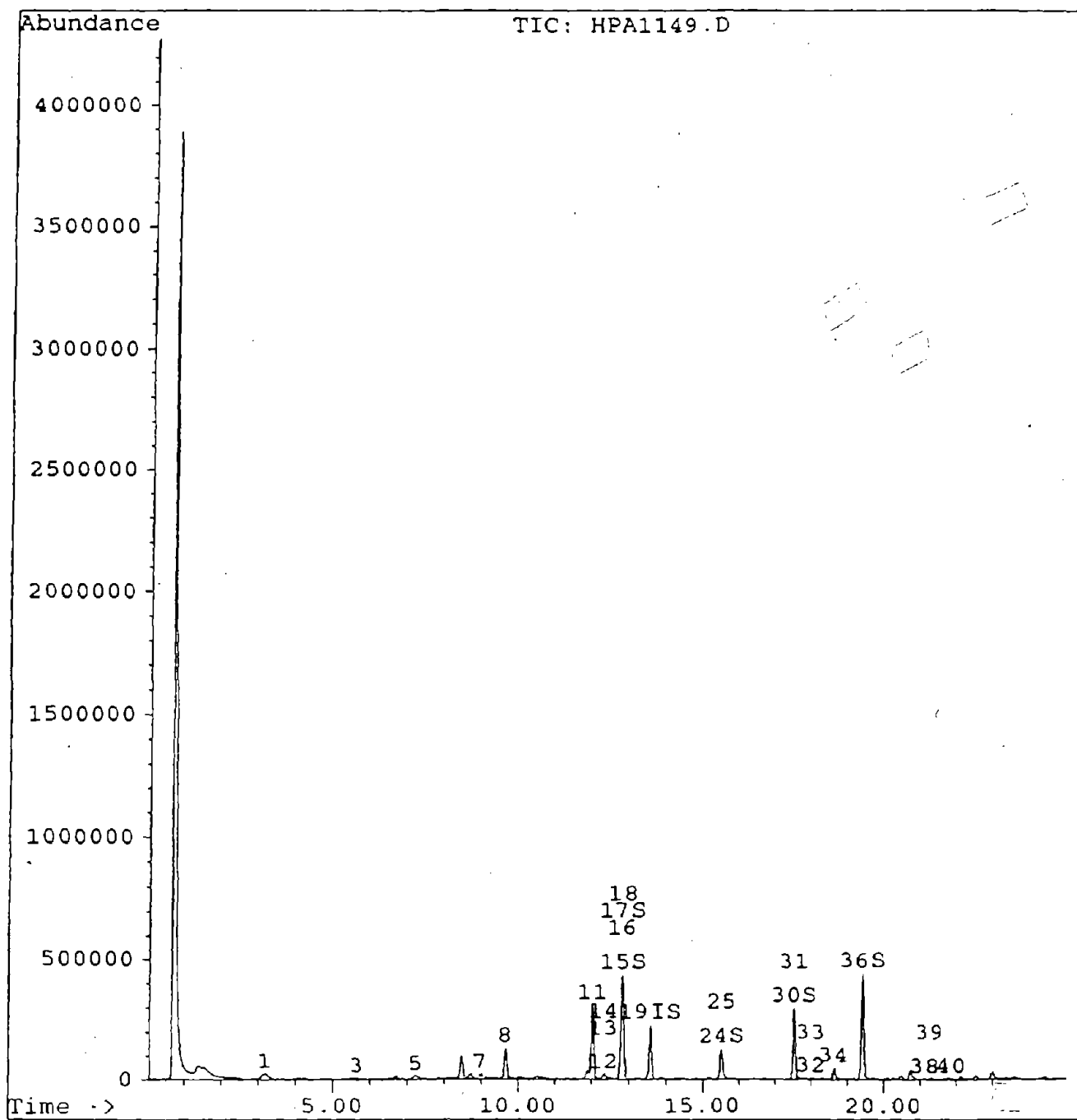Name: VOST,#463,#64 PULSED COMBUSTER,L,AIR,EPA,
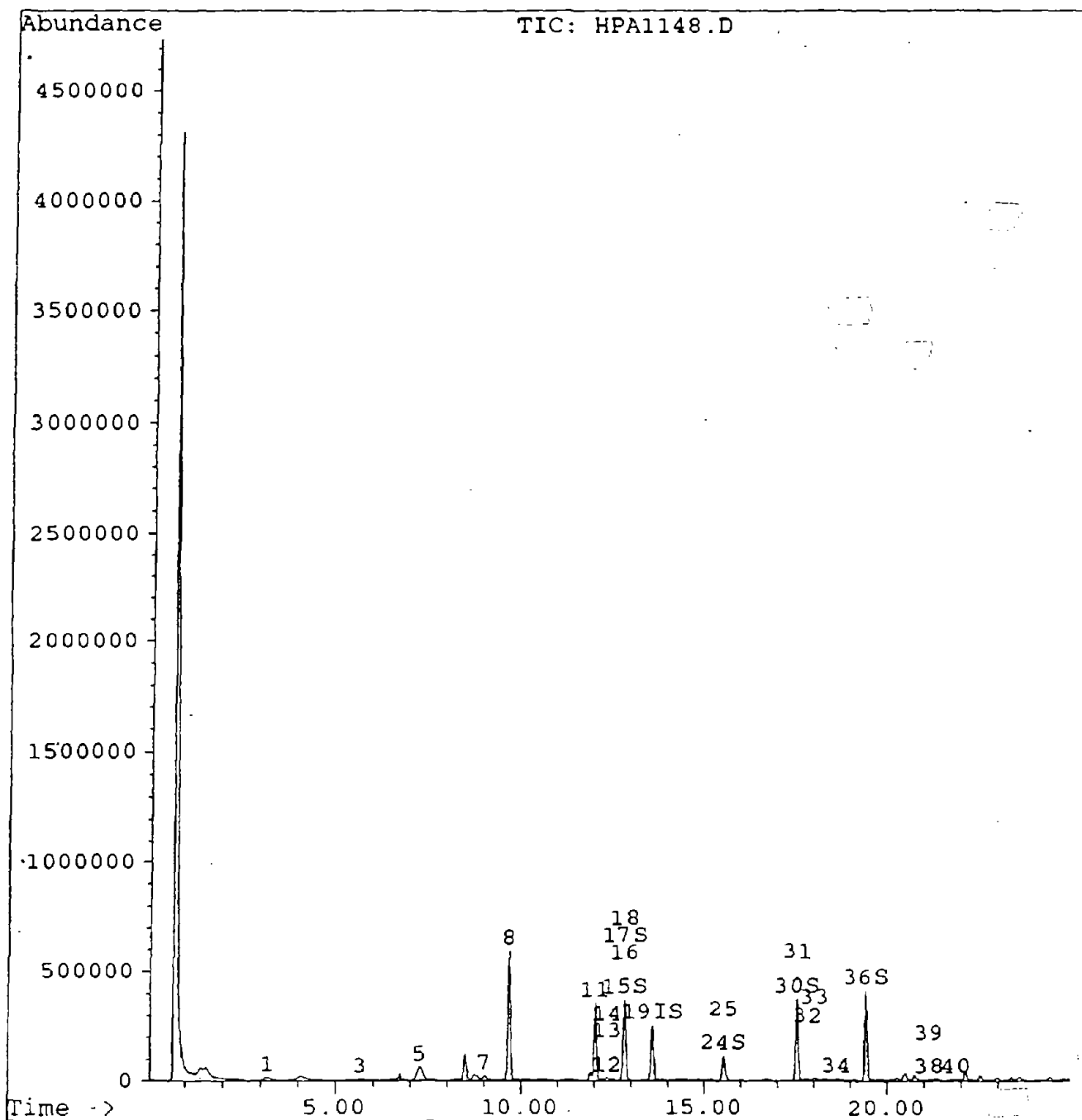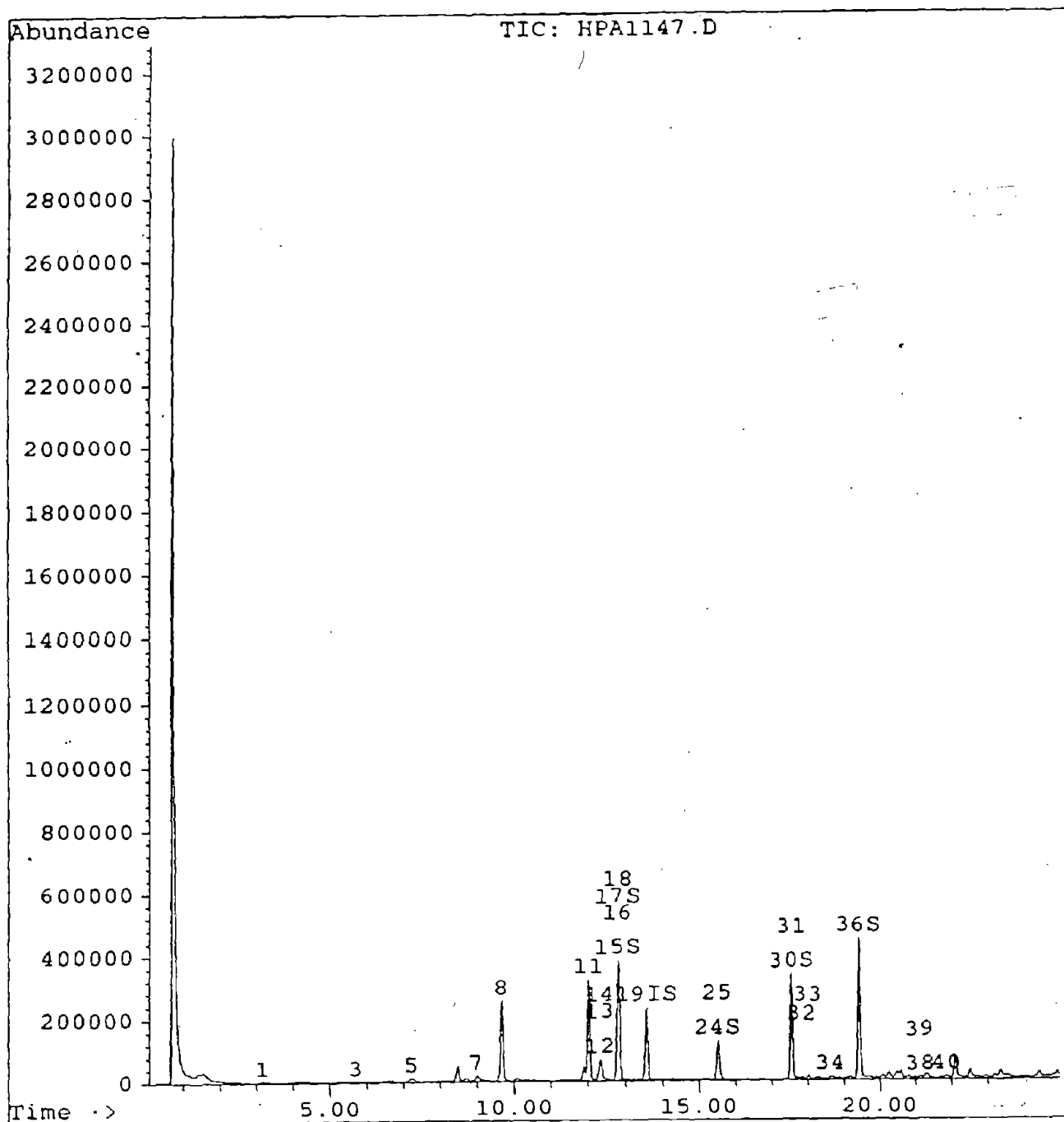Misc: QUANTS @ 250NG
Method: VOST.M
Title: 8240
Last Calibration: Mon Aug 17 22:02:16 1992

C:\CHEMPC\DATA\HPA1167.D   Fri Aug 21 10:37:35 1992   Page 3

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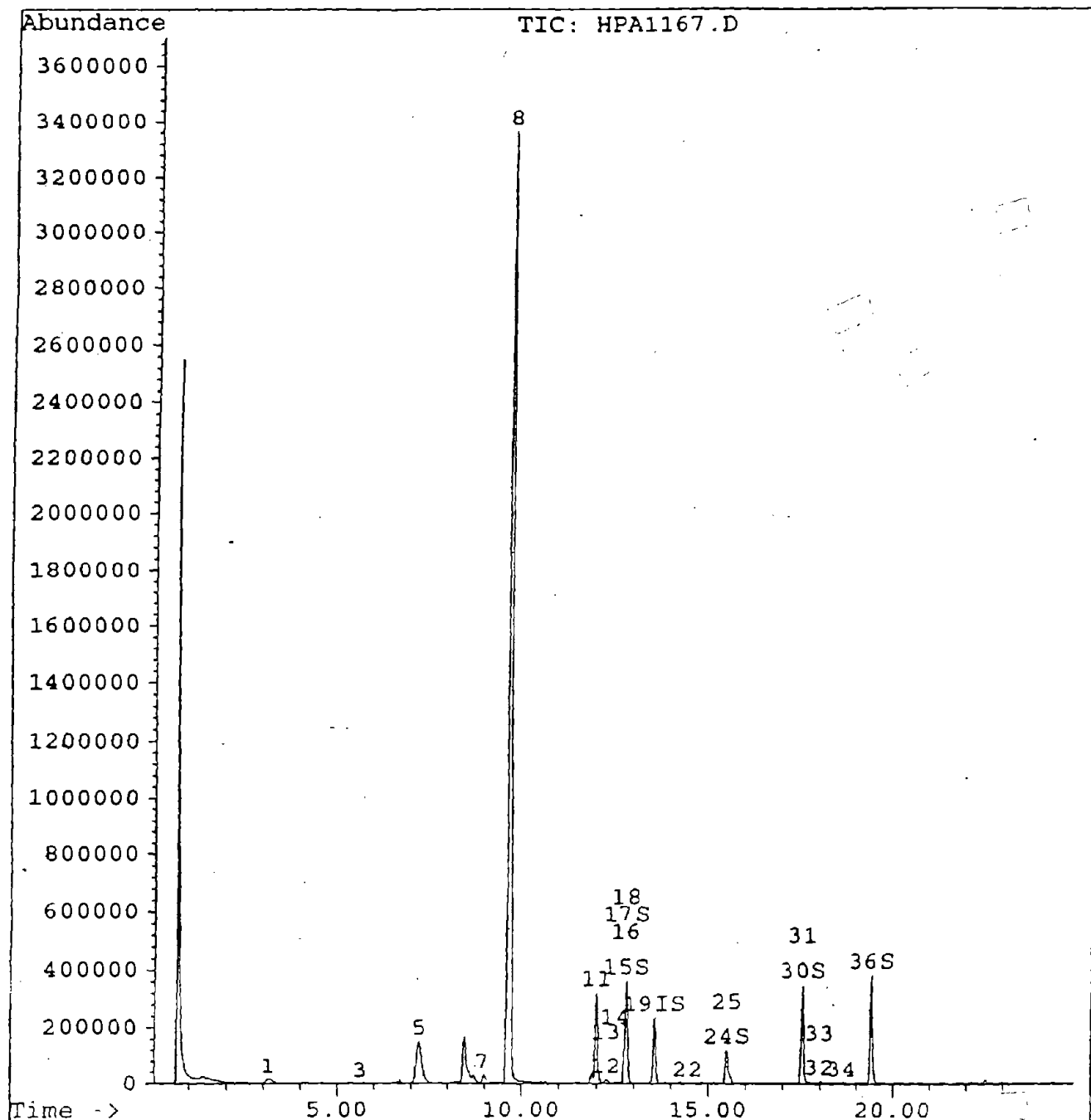
VOST CALIBRATION CHECK REPORT					
HPA1145.D					
08/10/92			Total ng		% Recovery	
chloromethane(spcc)			258		103	
vinyl chloride(ccc)			279		112	
bromomethane			270		108	
chloroethane			283		113	
trichlorofluoromethane			274		110	
1,1-dichloroethene(ccc)			364		145	
Acetone			149		60	
methylene chloride			277		111	
trans-1,2-dichloroethene			292		117	
1,1-dichloroethane(spcc)			263		105	
bromochloromethane (IS)			250		100	
chloroform(ccc)			266		106	
1,1,1-trichloroethane			273		109	
carbon tetrachloride			265		106	
d6-Benzene			518		104	
benzene			278		111	
d4-1,2-dichloroethane (surr)			268		107	
1,2-dichloroethane			256		102	
1,4-difluorobenzene (is)			250		100	
trichloroethene			262		105	
1,2-dichloropropane(ccc)			264		106	
bromodichloromethane			270		108	
cis-1,3-dichloropropene			272		109	
d8-toluene (surr)			261		105	
toluene(ccc)			276		110	
trans-1,3-dichloropropene			272		109	
1,1,2-trichloroethane			273		109	
tetrachloroethene			274		110	
dibromochloromethane			272		109	
d5-chlorobenzene (surr)			239		96	
chlorobenzene(spcc)			563		113	
ethyl benzene(ccc)			296		118	
m,p-xylene			198		40	
o-xylene			289		116	
bromoform(spcc)			251		101	
4-bromofluorobenzene (surr)			255		102	
1,1,2,2-tetrachloroethane(spcc)			247		99	
1,2-Dichlorobenzene			557		111	
1,4-Dichlorobenzene			575		115	
1,3-Dichlorobenzene			568		114	

VOST CALIBRATION CHECK REPORT						
HPA1154.D						
08/11/92			Total ng		% Recovery	
chloromethane(spcc)			247		99	
vinyl chloride(ccc)			202		81	
bromomethane			178		71	
chloroethane			220		88	
trichlorofluoromethane			250		100	
1,1-dichloroethene(ccc)			195		78	
Acetone			294		118	
methylene chloride			310		124	
trans-1,2-dichloroethene			253		101	
1,1-dichloroethane(spcc)			252		101	
bromochloromethane (IS)			250		100	
chloroform(ccc)			244		98	
1,1,1-trichloroethane			233		93	
carbon tetrachloride			232		93	
d6-Benzene			460		92	
benzene			294		118	
d4-1,2-dichloroethane (surr)			275		110	
1,2-dichloroethane			264		106	
1,4-difluorobenzene (is)			250		100	
trichloroethene			226		90	
1,2-dichloropropane(ccc)			235		94	
bromodichloromethane			249		100	
cis-1,3-dichloropropene			252		101	
d8-toluene (surr)			251		100	
toluene(ccc)			340		136	
trans-1,3-dichloropropene			257		103	
1,1,2-trichloroethane			258		103	
tetrachloroethene			256		102	
dibromochloromethane			265		106	
d5-chlorobenzene (surr)			235		94	
chlorobenzene(spcc)			510		102	
ethyl benzene(ccc)			294		118	
m,p-xylene			207		41	
o-xylene			288		115	
bromoform(spcc)			288		115	
4-bromofluorobenzene (surr)			212		85	
1,1,2,2-tetrachloroethane(spcc)			202		81	
1,2-Dichlorobenzene			639		128	
1,4-Dichlorobenzene			457		91	
1,3-Dichlorobenzene			510		102	

VOST CALIBRATION CHECK REPORT					
HPA1163.D					
08/16/92			Total ng		% Recovery
chloromethane(spcc)			245		98
vinyl chloride(ccc)			235		94
bromomethane			218		87
chloroethane			250		100
trichlorofluoromethane			288		115
1,1-dichloroethene(ccc)			229		92
Acetone			330		132
methylene chloride			351		141
trans-1,2-dichloroethene			289		116
1,1-dichloroethane(spcc)			280		112
bromochloromethane (IS)			250		100
chloroform(ccc)			280		112
1,1,1-trichloroethane			266		106
carbon tetrachloride			267		107
d6-Benzene			471		94
benzene			268		107
d4-1,2-dichloroethane (surr)			313		125
1,2-dichloroethane			299		120
1,4-difluorobenzene (is)			250		100
trichloroethene			257		103
1,2-dichloropropane(ccc)			272		109
bromodichloromethane			295		118
cis-1,3-dichloropropene			298		119
d8-toluene (surr)			289		116
toluene(ccc)			330		132
trans-1,3-dichloropropene			302		121
1,1,2-trichloroethane			296		119
tetrachloroethene			296		118
dibromochloromethane			313		125
d5-chlorobenzene (surr)			234		93
chlorobenzene(spcc)			523		105
ethyl benzene(ccc)			265		106
m,p-xylene			519		104
o-xylene			255		102
bromoform(spcc)			309		124
4-bromofluorobenzene (surr)			228		91
1,1,2,2-tetrachloroethane(spcc)			208		83
1,2-Dichlorobenzene			632		126
1,4-Dichlorobenzene			507		101
1,3-Dichlorobenzene			503		101

Appendix B

DRE Calculations

<u>DRE Calculations for</u>
<u>Principal Organic Hazardous Constituents (POHCs)</u>

Pulsing Mode

<u>Results:</u>   Stack Emissions of carbon tetrachloride and chlorobenzene were below detection limits in all cases.

Practical Quantitation Limit (for volatile organics) = 1 ng/L

Given a stack flow rate = 40.57 scfm = 1148.8 L/min and a POHC input = 3.48 g/min, the following minimum DRE value is calculated:

(1ng/L)(1148.8 L/min)(1μg/1000 ng) = 1.1488 μg/ min

DRE = (Input - Output)/ Input

DRE = <u>3.48 g/min- (1.1488 μg/min)(1g/10$^6\mu$g)</u>
                     3.48g/min

DRE (minimum) = 99.999967

Non-Pulsing Mode

<u>Results:</u>

(1)   For carbon tetrachloride, the exit concentrations were less than the detection limit, so DRE numbers will be the same as the pulsing mode.

(2)   For chlorobenzene, two of the three replicate VOST runs had detectable concentrations in the stack gas. These two exit concentrations equate to the following DRE results:

<u>Exit Concentration</u> = 1.4 ng/L

(1.4 ng/L)(1148.8 L/min)(1μg/1000ng) = 1.6083 μg/min

DRE = [3.48 g/min - (1.6083 μg/min)(1g/10^6 μg)]/ 3.48g/min

DRE = 99.999954

<u>Exit Concentration</u> = 1.1 ng/L

(1.1 ng/L)(1148.8 L/min)(1μg/1000ng) = 1.2637 μg/min

DRE = [3.48 g/min - (1.2637 μg/min)(1g/10^6 μg)]/ 3.48g/min

DRE = 99.999964

Appendix C

Semivolatile Organic Screening Results

GeoChem, Incorporated

Environmental Laboratories

Geochem(NC #336/SC #99008)
Project#9301-028   1   Site Name Pulsed Combuster

LAB ID.	0092	0093	0094
DATE ANALYZED	01/20/93	01/20/93	01/20/93
FIELD ID.	PC92-07-13-01	PC92-07-15-01	PC92-07-16-01

METHOD

ANALYTE	ng/ul	ng/ul	ng/ul

8270 Base/Neutrals

ANALYTE	ng/ul	ng/ul	ng/ul
N-Nitrosodimethylamine	< 5	< 5	< 5
Aniline	< 5	< 5	< 5
Bis2Chloroethyl Ether	< 5	< 5	< 5
1,3-Dichlorobenzene	< 5	< 5	< 5
1,4-Dichlorobenzene	< 5	< 5	< 5
1,2-Dichlorobenzene	< 5	< 5	< 5
Benzyl Alcohol	< 10	< 10	< 10
Bis2ChloroisopropylEthr	< 5	< 5	< 5
Hexachloroethane	< 5	< 5	< 5
N-Nitrosodipropylamine	< 5	< 5	< 5
Nitrobenzene	< 5	< 5	< 5
Isophorone	38	360	15
Bis2ChloroethoxyMethane	< 5	< 5	< 5
1,2,4-Trichlorobenzene	< 5	< 5	< 5
Naphthalene	3.4J	2.9J	2.8J
Benzoic Acid	< 25	260	260
4-Chloroaniline	< 5	< 5	< 5
Hexachlorobutadiene	< 5	< 5	< 5
2-Methylnaphthalene	< 5	< 5	< 5
Hexachlorcyclopentadien	< 5	< 5	< 5
2-Chloronaphthalene	< 5	< 5	< 5
2-Nitroaniline	< 25	< 25	< 25
Acenaphthylene	< 5	< 5	< 5
Dimethylphthalate	< 5	< 5	< 5
2,6-Dinitrotoluene	< 5	< 5	< 5
Acenaphthene	< 5	< 5	< 5
3-Nitroaniline	< 25	< 25	< 25
Dibenzofuran	< 5	< 5	< 5
2,4,Dinitrotoluene	< 5	< 5	< 5
Fluorene	< 5	< 5	< 5
4ChlorophenylPhenylEthe	< 5	< 5	< 5
Diethylphthalate	4.1J	3.8J	3.8J
4-Nitroaniline	< 25	< 25	< 25
N-Nitrosodiphenylamine	< 5	< 5	< 5
Azobenzene	< 25	< 25	< 25
4-Bromophenyl PhenylEth	< 5	< 5	< 5
Hexachlorobenzene	< 5	< 5	< 5

	soil	water
parts per million =	mg/kg	mg/l
parts per billion =	ug/kg	ug/l

pql = practical quantitation limit due to matrix effects.
bdl = below method detection limit.
bql = below quantitation limit.
J   = estimated concentration.

GeoChem, Incorporated

Environmental Laboratories

LAB ID.	0092	0093	0094
DATE ANALYZED	01/20/93	01/20/93	01/20/93
FIELD ID.	PC92-07-13-01	PC92-07-15-01	PC92-07-16-01

METHOD

ANALYTE	ng/ul	ng/ul	ng/ul

8270 Base/Neutrals continued

Anthracene	< 5	< 5	< 5
Phenanthrene	6.8	12	4.5J
Di-N-Butylphthalate	46	51	71
Fluoranthene	< 5	< 5	< 5
Pyrene	< 5	< 5	< 5
Benzidine	< 25	220	< 25
Indeno(1,2,3-cd)Pyrene	< 5	< 5	< 5
Butyl Benzyl Phthalate	< 10	< 10	< 10
Chrysene	< 5	< 5	< 5
Benzo(a)Anthracene	< 5	< 5	< 5
3,3'-Dichlorobenzidine	< 10	< 10	< 10
Bis2EthylhexylPhthalate	53	21	920
Di-N-Octylphthalate	< 5	< 5	< 5
Benzo(B)Fluoranthene	< 5	< 5	< 5
Benzo(k)Fluoranthene	< 5	< 5	< 5
Benzo(a)Pyrene	< 5	< 5	< 5
Dibenz(a,h)Anthracene	< 5	< 5	< 5
Benzo(g,h,i)Perylene	< 5	< 5	< 5

8270 Acid Extractables

2-Chlorophenol	< 5	< 5	< 5
Phenol	< 5	< 5	< 5
2-Nitrophenol	< 5	< 5	< 5
2-Methylphenol	< 5	< 5	< 5
4-Methylphenol	< 5	< 5	< 5
2,4-Dimethylphenol	< 5	< 5	< 5
2,4-Dichlorophenol	< 5	< 5	< 5
4-Chloro-3-Methylphenol	< 10	< 10	< 10
2,4,5-Trichlorophenol	< 5	< 5	< 5
2,4,6-Trichlorophenol	< 5	< 5	< 5
2,4-Dinitrophenol	< 5	< 5	< 5
4-Nitrophenol	< 25	< 25	< 25
4,6-Dinitro-2Methylphen	< 5	< 5	< 5
Pentachlorophenol	< 5	< 5	< 5

```
                    soil    water
parts per million = mg/kg    mg/l
parts per billion = ug/kg    ug/l
pql = practical quantitation limit due to matrix effects.
bdl = below method detection limit.
bql = below quantitation limit.
J   = estimated concentration.
```

GeoChem, Incorporated

Environmental Laboratories

Geochem(NC #336/SC #99008)
Project#9301-028   3   Site Name Pulsed Combuster

LAB ID.	0095	0096	0097
DATE ANALYZED	01/20/93	01/20/93	01/20/93
FIELD ID.	PC92-07-22-01	PC92-07-30-01	GW92-10-14-01

METHOD

ANALYTE	ng/ul	ng/ul	ng/ul

8270 Base/Neutrals

N-Nitrosodimethylamine	< 5	< 5	< 5
Aniline	< 5	< 5	< 5
Bis2Chloroethyl Ether	< 5	< 5	< 5
1,3-Dichlorobenzene	< 5	< 5	< 5
1,4-Dichlorobenzene	< 5	< 5	< 5
1,2-Dichlorobenzene	< 5	< 5	< 5
Benzyl Alcohol	< 10	< 10	< 10
Bis2ChloroisopropylEthr	< 5	< 5	< 5
Hexachloroethane	< 5	< 5	< 5
N-Nitrosodipropylamine	< 5	< 5	< 5
Nitrobenzene	< 5	< 5	< 5
Isophorone	< 5	< 5	< 5
Bis2ChloroethoxyMethane	< 5	< 5	< 5
1,2,4-Trichlorobenzene	< 5	< 5	< 5
Naphthalene	< 5	< 5	< 5
Benzoic Acid	170	< 5	< 5
4-Chloroaniline	< 5	< 5	< 5
Hexachlorobutadiene	< 5	< 5	< 5
2-Methylnaphthalene	< 5	< 5	< 5
Hexachlorcyclopentadien	< 5	< 5	< 5
2-Chloronaphthalene	< 5	< 5	< 5
2-Nitroaniline	< 25	< 25	< 25
Acenaphthylene	< 5	< 5	< 5
Dimethylphthalate	9.0	< 5	< 5
2,6-Dinitrotoluene	< 5	< 5	< 5
Acenaphthene	< 5	< 5	< 5
3-Nitroaniline	< 25	< 25	< 25
Dibenzofuran	< 5	< 5	< 5
2,4,Dinitrotoluene	< 5	< 5	< 5
Fluorene	< 5	< 5	< 5
4ChlorophenylPhenylEthe	< 5	< 5	< 5
Diethylphthalate	2.8J	2.2J	< 5
4-Nitroaniline	< 25	< 25	< 25
N-Nitrosodiphenylamine	< 5	< 5	< 5
Azobenzene	< 25	< 25	< 25
4-Bromophenyl PhenylEth	< 5	< 5	< 5
Hexachlorobenzene	< 5	< 5	< 5

```
                      soil    water
parts per million = mg/kg    mg/l
parts per billion = ug/kg    ug/l
pql = practical quantitation limit due to matrix effects.
bdl = below method detection limit.
bql = below quantitation limit.
J   = estimated concentration.
```

GeoChem, Incorporated

Environmental Laboratories

Geochem(NC #336/SC #99008)
Project#9301-028   4   Site Name Pulsed Combuster

LAB ID.	0095	0096.	0097
DATE ANALYZED	01/20/93	01/20/93	01/20/93
FIELD ID.	PC92-07-22-01	PC92-07-30-01	GEB92-10-14-01

METHOD

ANALYTE	ng/ul	ng/ul	ng/ul

8270 Base/Neutrals continued

Anthracene	< 5	< 5	< 5
Phenanthrene	< 5	< 5	< 5
Di-N-Butylphthalate	57	43	74
Fluoranthene	< 5	< 5	< 5
Pyrene	< 5	< 5	< 5
Benzidine	< 25	< 5	< 25
Indeno(1,2,3-cd)Pyrene	< 5	< 5	< 5
Butyl Benzyl Phthalate	< 10	< 10	< 10
Chrysene	< 5	< 5	< 5
Benzo(a)Anthracene	< 5	< 5	< 5
3,3'-Dichlorobenzidine	< 10	< 10	< 10
Bis2EthylhexylPhthalate	110	260	< 5
Di-N-Octylphthalate	< 5	< 5	< 5
Benzo(B)Fluoranthene	< 5	< 5	< 5
Benzo(k)Fluoranthene	< 5	< 5	< 5
Benzo(a)Pyrene	< 5	< 5	< 5
Dibenz(a,h)Anthracene	< 5	< 5	< 5
Benzo(g,h,i)Perylene	< 5	< 5	< 5

8270 Acid Extractables

2-Chlorophenol	< 5	< 5	< 5
Phenol	< 5	< 5	< 5
2-Nitrophenol	< 5	< 5	< 5
2-Methylphenol	< 5	< 5	< 5
4-Methylphenol	< 5	< 5	< 5
2,4-Dimethylphenol	< 5	< 5	< 5
2,4-Dichlorophenol	< 5	< 5	< 5
4-Chloro-3-Methylphenol	< 10	< 10	< 10
2,4,5-Trichlorophenol	< 5	< 5	< 5
2,4,6-Trichlorophenol	< 5	< 5	< 5
2,4-Dinitrophenol	< 5	< 5	< 5
4-Nitrophenol	< 25	< 25	< 25
4,6-Dinitro-2Methylphen	< 5	< 5	< 5
Pentachlorophenol	< 5	< 5	< 5

	soil	_water_
parts per million =	mg/kg	mg/l
parts per billion =	ug/kg	ug/l

pql = practical quantitation limit due to matrix effects.
bdl = below method detection limit.
bql = below quantitation limit.
J   = estimated concentration.

Tentatively Identified Compounds(TIC'S) For Pulsed Combuster Sample's.

Sample ID: Test 1 (7/13/92) Oil only - High Noise

Lab ID: PC92-07-13-01

GC/MS ID: 9301-028-0092

CAS NUMBER	COMPOUND NAME	RT	SAMPLE MASS(ug/ml)
	Trimethylbenzene isomer	11.1	16.69
791-28-6	Phosphine oxide,triphenyl	35.2	67.49
54340-86-2	Benzene,4(2-butenyl)-1,2-dimethyl	17.8	8.29

Sample ID: Test 2 (7/15/92) Oil only - Low Noise

Lab ID: PC92-07-15-92

GC/MS ID: 9301-028-0093

CAS NUMBER	COMPOUND NAME	RT	SAMPLE MASS(ug/ml)
	Trimethylbenzene isomer	11.1	63.1
2084-69-7	Naphthalene,tetrahydro	23.9	19.93
54340-86-2	Benzene,4(2-butenyl)-1,2-dimethyl	17.8	25.7

Sample ID: Test 3 (7/16/92) Chlorobenzene and Carbontetrachloride - High Noise

Lab ID: PC92-07-16-01

GC/MS ID:9301-028-0094

No Tic's qualified for the positive identification threshold.

Sample ID: Test 4 (7/22/92) Chlorobenzene and Carbontetrachloride - Low Noise

Lab ID: PC92-07-22-01

GC/MS ID: 9301-028-0095

 No Tic's qualified for the positive identification threshold.

Sample ID: TEST 5 (7/30/92) Trip Blank

Lab ID: PC92-07-30-01

GC/MS ID: 9301-028-0096

 No Tic's qualified for the positive identification threshold.

Sample ID: Test 6 Laboratory Blank.

LAB ID: GWB92-10-14-01

GC/MS ID: 9301-028-0097

 No Tic's qualified for the positive identification threshold.

Note: Posivive identification threshold means that any unknown peak search
     against a reference library of known spectra must agree at 80% or
     better with the fragmentation pattern of the unknown and the mass
     intensities(m/e) of each fragment ion against the reference spectra.
     Also the chemist's judgement is considered.

Appendix D

Particulate Loading Results

Modified Method 5 Volume and Moisture Calculation Worksheet

PROJECT: Pulse combustion DATE: 7/16/92
TEST: CCl4 and Chlorobenzene feed
LOCATION: Rainbow furnace TEST #: 3
TEST PARAMETERS: Pulse on Bar Pressure: 29.92

avg or net

										avg or net
Amb temp	80	80	80	80	82	84	84	82		81.00
Volume cu ft	202.90	209.2	217.7	232.4	248.4	287	298.9	303.47		100.57
Last Imping										0.00
Meter In	90	112	117	117	117	114	116	117		112.50
Meter Out	82	90	92	102	104	100	101	102		96.63
Flow DH	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54		0.54
XAD Temp	32	32.	32	32	32	32	32	32		32.00
Stack T in	829	662	667	674	673	711	719	733		708.50
Stack T out										0.00
Pump vac	5.2	5.2	5.2	5.2	5.2	5.6	5.6	5.6		5.35

Uncorrected volume
of gas sampled= 100.56 cubic feet

Average stack temp= 1168.5 deg R

Meter Inlet 572.5 deg R
Meter Outlet 556.62 deg R
Meter Average 564.56 deg R

Sampling duration= 221 minutes

901 water recovered in impingers
38 water collected in SiO2
939 total final water volume
705 initial water volume
234 total condensed

11.014 volume of water as gas at stp in cubic feet
-92.520 volume of dry gas (from meter) at stp in cubic feet
103.53 total gas volume at stp in cubic feet

10.638 percent moisture in gas sampled

correction factor of dry gas meter used = 0.98

ISOKINETICITY AND PARTICULATE LOADING SUMMARY

PROJECT: Pulse combustion
TEST: CCl4 and Chlorobenzene feed w/pulse on
LOCATION: Rainbow furnace

TEST #: 3
RUN PARAMETERS: pulse on; FR = 200000 BTU/hr

DATE: 16 Jul 92

Stack diameter (inches)		6.00
Pitot corr factor S type= 0.85cp		0.85
Straight type= 0.99cp		
Stack temp (deg R)		1166.00
Molecular weight of gas (g/mol)		29.00
	1.14	1.07
Stack gas velocity (ft/s) (at stack conditions)		4.27
Gas volume exiting stack (ACFM)		83.41
Gas volume exiting stack (SCFM)		40.57
Gas volume exiting stack (SCMH)		68.94

CALCULATED ISOKINETIC VARIATION

Total volume of water condensed (ml)		234.00
Uncorrected gas volume from meter (cubic feet)		100.50
Average meter temp (deg R)		564.50
Orifice delta H (inches H2O)	not measured	
Sampling duration (minutes)		221.00
Sample nozzle diameter (inches)		0.84
Nozzle face area (square feet)		0.0039
Barometric Pressure (inches Hg)		29.92
Stack pressure (in Hg)		29.92
Stack pressure corrected for delta H (in Hg)		29.92

Sample was collected at   103.81 percent of isokinetic

SAMPLE GAS VOLUME AND PARTICULATE DATA

Corrected dry volume from meter (cubic feet at meter temp)	98.49
Dry volume corrected to stp (cubic feet)	92.47
Dry volume corrected to stp (cubic meters)	2.62
Volume of condensed water as gas at stp (cubic feet)	11.01
Total wet volume of gas at stp (cubic feet)	103.48
Percent moisture of gas sampled	10.64
Mass of particulate captured (grams)	0.1288

Particulate loading:
(mg solids/cu ft wet gas)	1.2442
(mg solids/cu mtr wet gas)	43.9384
(mg solids/cu ft dry gas)	1.3923
(mg solids/cu mtr dry gas)	49.1699

Modified Method 5 Volume and Moisture Calculation Worksheet

PROJECT: Pulse combustion   DATE: 7/22/92
TEST: CCl4 and Chlorobenzene
LOCATION: Rainbow furnace   TEST #:   4
TEST PARAMETERS: Oil feed, low noise   Bar Pressure: 29.92

avg or net

										avg or net
Amb temp	83	85	86	85	85	86	84	83	85	85.00
Volume cu ft	303.67	306.7	318.8	331	350.1	364.7	386.4	400.7	413.52	109.85
Last Imping										0.00
Meter In	88	100	110	115	118	116	118	118	118	111.44
Meter Out	84	84	86	94	104	104	108	108	109	97.89
Flow DH	0.54	0.53	0.54	0.47	0.465	0.46	0.45	0.45		0.43
XAD Temp	32	32	32	32	32	32	32	32	32	32.00
Stack T in	917	815	823	826	825	821	817	817	816	830.78
Stack T out										0.00
Pump vac	5.2	5.8	6.0	6.2	6.2	6.2	6.4	6.4	6.4	6.1

Uncorrected volume
of gas sampled=   109.84   cubic feet

Average stack
temp=   1290.7   deg R

Meter Inlet   571.44   deg R
Meter Outlet   557.88   deg R
Meter Average   564.66   deg R

Sampling
duration=   251   minutes

806   water recovered in impingers
29   water collected in SiO2
835   total final water volume
577   initial water volume
258   total condensed

12.144   volume of water as gas at stp in cubic feet
101.03   volume of dry gas (from meter) at stp in cubic feet
113.18   total gas volume at stp in cubic feet

10.729   percent moisture in gas sampled

correction factor of dry gas meter used =   0.98

ISOKINETICITY AND PARTICULATE LOADING SUMMARY

PROJECT: Pulse combustion
TEST: CCl4 and Chlorobenzene w/pulse off
LOCATION: Rainbow furnace

TEST #: 4
RUN PARAMETERS: Oil feed; low noise;
Firing rate = 200000 BTU/hr

DATE: 22 Jul 92

Stack diameter (inches)	8.00
Pitot corr factor S type= 0.85cp	0.85
Straight type= 0.99cp	
Stack temp (deg R)	1290.00
Molecular weight of gas (g/mol)	29.00
	1.26
Stack gas velocity (ft/s) (at stack conditions)	4.71
Gas volume exiting stack (ACFM)	96.75
Gas volume exiting stack (SCFM)	40.57
Gas volume exiting stack (SCMH)	68.94

Molecular weight of gas value 1.12 appears right-aligned below 29.00

CALCULATED ISOKINETIC VARIATION

Total volume of water condensed (ml)	258.00
Uncorrected gas volume from meter (cubic feet)	109.60
Average meter temp (deg R)	564.60
Orifice delta H (inches H2O)	not measured
Sampling duration (minutes)	251.00
Sample nozzle diameter (inches)	0.84
Nozzle face area (square feet)	0.0039
Barometric Pressure (inches Hg)	29.92
Stack pressure (in Hg)	29.92
Stack pressure corrected for delta H (in Hg)	29.82

Sample was collected at   99.94 percent of isokinetic

SAMPLE GAS VOLUME AND PARTICULATE DATA

Corrected dry volume from meter (cubic feet at meter temp)	107.60
Dry volume corrected to stp (cubic feet)	101.01
Dry volume corrected to stp (cubic meters)	2.86
Volume of condensed water as gas at stp (cubic feet)	12.14
Total wet volume of gas at stp (cubic feet)	113.15
Percent moisture of gas sampled	10.73
Mass of particulate captured (grams)	0.1289

Particulate loading:

(mg solids/cu ft wet gas)	1.1389
(mg solids/cu mtr wet gas)	40.2212
(mg solids/cu ft dry gas)	1.2758
(mg solids/cu mtr dry gas)	45.0552

Modified Method 5 Volume and Moisture Calculation Worksheet

PROJECT: Pulse combustion   DATE: 7/13/92
TEST: Oil baseline
LOCATION: Rainbow furnace   TEST #:   1
TEST PARAMETERS: Oil feed, high noise   Bar Pressure: 29.92

avg or net

										avg or net
Amb temp										0.00
Volume cu ft	92.078	96.5	101.2	110.1	139.6	156.5	170.1	181.9	215.24	123.17
Last Imping										0.00
Meter In	84	102	108	114	117	117	117	117	117	110.33
Meter Out	80	82	84	98	102	102	100	102	102	94.67
Flow DH										0.00
XAD Temp	32	32	32	32	32	32	32	32	32	32.00
Stack T In	742	740		754		778	779	789	789	767.29
Stack T out										0.00
Pump vac	5.5	5.7	5.7	5.7	6	6.2	6.2	6.2	6.2	5.93

Uncorrected volume
of gas sampled=   123.16   cubic feet   Average stack
                                                    temp=   1227.2   deg R

Meter Inlet   570.33   deg R   Sampling
Meter Outlet   554.66   deg R   duration=   246   minutes
Meter Average   562.5   deg R

          926   water recovered in impingers
          34   water collected in SiO2
          960   total final water volume
          712   initial water volume
          248   total condensed

          11.673   volume of water as gas at stp in cubic feet
          113.73   volume of dry gas (from meter) at stp in cubic feet
          125.40   total gas volume at stp in cubic feet

          9.3085   percent moisture in gas sampled

correction factor of dry gas meter used =   0.98

ISOKINETICITY AND PARTICULATE LOADING SUMMARY

PROJECT: Pulse combustion
TEST: Oil baseline - Pulse on
LOCATION: Rainbow furnace

TEST #:   1
RUN PARAMETERS: Oil feed; pulse on;
                       Firing rate = 200000 BTU/hr

DATE: 13 Jul 92

Stack diameter (inches)	6.00
Pitot corr factor S type= 0.85cp	0.85
Straight type= 0.89cp	
Stack temp (deg R)	1227.00
Molecular weight of gas (g/mol)	29.00
	1.20
	1.10
Stack gas velocity (ft/s) (at stack conditions)	4.48
Gas volume exiting stack (ACFM)	93.92
Gas volume exiting stack (SCFM)	40.57
Gas volume exiting stack (SCMH)	68.94

CALCULATED ISOKINETIC VARIATION

Total volume of water condensed (ml)	248.00
Uncorrected gas volume from meter (cubic feet)	123.10
Average meter temp (deg R)	562.50
Orifice delta H (inches H2O)	not measured
Sampling duration (minutes)	246.00
Sample nozzle diameter (inches)	0.84
Nozzle face area (square feet)	0.0039
Barometric Pressure (inches Hg)	29.92
Stack pressure (in Hg)	29.92
Stack pressure corrected for delta H (in Hg)	29.92

Sample was collected at	112.95 percent of isokinetic

SAMPLE GAS VOLUME AND PARTICULATE DATA

Corrected dry volume from meter (cubic feet at meter temp)	120.64
Dry volume corrected to stp (cubic feet)	113.67
Dry volume corrected to stp (cubic meters)	3.22
Volume of condensed water as gas at stp (cubic feet)	11.67
Total wet volume of gas at stp (cubic feet)	125.34
Percent moisture of gas sampled	9.31
Mass of particulate captured (grams)	0.0769

Particulate loading:

(mg solids/cu ft wet gas)	0.6136
(mg solids/cu mtr wet gas)	21.6699
(mg solids/cu ft dry gas)	0.6766
(mg solids/cu mtr dry gas)	23.8947

Modified Method 5 Volume and Moisture Calculation Worksheet

PROJECT: Pulse combustion   DATE: 7/15/92
TEST: Oil baseline
LOCATION: Rainbow furnace   TEST #:   2
TEST PARAMETERS: Oil feed, no pulse   Bar Pressure: 29.92

avg or net

											avg or net
Amb temp											0.00
Volume cu ft	6.754	12.7	22.2	39.4	52	63.2	90	100.88			94.13
Last Imping											0.00
Meter In	84	98	110	117	114	112	112	112			107.38
Meter Out	78	80	90	100	102	104	104	104			95.25
Flow DH											0.00
XAD Temp	32	32	32	32	32	32	32	32			32.00
Stack T In	669	690	692	702	710	718	727	730			704.75
Stack T out											0.00
Pump vac	5.8	5.5	5.8	5.8	5.8	5.8	6	6			5.81

Uncorrected volume
of gas sampled=   94.128   cubic feet

Average stack
temp=   1164.7   deg R

Meter Inlet   567.37   deg R
Meter Outlet   555.25   deg R
Meter Average   561.31   deg R

Sampling
duration=   206   minutes

796   water recovered in impingers
31   water collected in SiO2
827   total final water volume
609   initial water volume
218   total condensed

10.261   volume of water as gas at stp in cubic feet
87.099   volume of dry gas (from meter) at stp in cubic feet
97.360   total gas volume at stp in cubic feet

10.539   percent moisture in gas sampled

correction factor of dry gas meter used =   0.98

ISOKINETICITY AND PARTICULATE LOADING SUMMARY

PROJECT: Pulse combustion
TEST: Oil baseline - Pulse off
LOCATION: Rainbow furnace

TEST #: 2
RUN PARAMETERS: Oil feed, no pulse
Firing rate = 200000 BTU/hr

DATE: 15 Jul 92

Stack diameter (inches)	8.00
Pitot corr factor S type= 0.85cp	0.85
Strai ght type= 0.99cp	
Stack temp (deg R)	1164.00
Molecular weight of gas (g/mol)	29.00
	1.14
	1.07
Stack gas velocity (ft/s) (at stack conditions)	4.25
Gas volume exiting stack (ACFM)	89.10
Gas volume exiting stack (SCFM)	40.57
Gas volume exiting stack (SCMH)	68.94

CALCULATED ISOKINETIC VARIATION

Total volume of water condensed (ml)	218.00
Uncorrected gas volume from meter (cubic feet)	94.12
Average meter temp (deg R)	561.30
Orifice delta H (inches H2O)	not measured
Sampling duration (minutes)	206.00
Sample nozzle diameter (inches)	0.84
Nozzle face area (square feet)	0.0039
Barometric Pressure (inches Hg)	29.92
Stack pressure (in Hg)	29.92
Stack pressure corrected for delta H (in Hg)	29.92

Sample was collected at   104.77 percent of isokinetic

SAMPLE GAS VOLUME AND PARTICULATE DATA

Corrected dry volume from meter (cubic feet at meter temp)	92.24
Dry volume corrected to stp (cubic feet)	87.09
Dry volume corrected to stp (cubic meters)	2.47
Volume of condensed water as gas at stp (cubic feet)	10.26
Total wet volume of gas at stp (cubic feet)	97.35
Percent moisture of gas sampled	10.54
Mass of particulate captured (grams)	0.0050

Particulate loading:

(mg solids/cu ft wet gas)	0.0516
(mg solids/cu mtr wet gas)	1.8210
(mg solids/cu ft dry gas)	0.0576
(mg solids/cu mtr dry gas)	2.0355

THIS SPREADSHEET BEGUN 8/4/92 BY CCL TO SUMMARIZE PULSED COMBUSTOR FILTER WEIGHTS
ORIGINAL DATA ON P100 OF RTs SAMPLING NOTEBOOK AND ON P82 OF CCLs GENERAL VOL II NOTEBOOK

FILTER #	PRESAMPLING WEIGHT (g)	DATE SAMPLED	CONDITION SAMPLED	POSTSAMPLING WEIGHT (g)	NET WEIGHT GAIN (g)	FILTER COLOR AFTER SAMPLING
RP1	0.59837	7/13/92	OIL - HIGH NOISE	0.67528	0.07691	VERY VERY LIGHT TAN
RP2	0.59768	7/15/92	OIL - LOW NOISE	0.6027	0.00502	VERY LIGHT TAN
RP4	0.59504	7/16/92	CHLOROBENZENE AND CCl4-HIGH NOISE	0.72379	0.12875	LIGHT TAN
RP5	0.59934	7/22/92	CHLOROBENZENE AND CCl4-LOW NOISE	0.72821	0.12887	LIGHT TAN WITH BLACK
RP10	0.59368	NA	TRIP BLANK	0.59417	0.00049	WHITE

From Acurex NB #1403 PP 86-87

Appendix E

Particle Size Distribution Results

TSI DIFFERENTIAL MOBILITY PARTICLE SIZER
NON-PULSE BACKGROUND 7/15/92

SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
MAXIMUM DIA. MEASURED: .886 UM   START: 14:52:25
DATE: 07-15-1992   MINIMUM DIA. MEASURED: .017 UM   END: 15:08:59

		CONCENTRATION			PERCENTAGE		
DIA CH#	DIAMETER MIDPOINT (UM)	NUMBER (#/CC)	SURFACE (UM^2/CC)	VOLUME (UM^3/CC)	NUMBER	SURFACE CUMULATIVE PERCENTAGE	VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	1.87E 5	215.261	.686	37.392	3.4	.111
6	.022	1.62E 5	248.015	.912	69.699	7.316	.26
7	.025	8.86E 4	180.865	.768	87.366	10.173	.385
8	.029	3.70E 4	100.818	.494	94.751	11.765	.465
9	.034	1.33E 4	48.512	.275	97.416	12.531	.51
10	.039	1690.329	8.178	5.34E-2	97.753	12.66	.518
11	.045	331.779	2.269	1.71E-2	97.823	12.696	.521
12	.052	177.604	1.528	1.33E-2	97.858	12.72	.523
13	.06	1420.249	16.293	.164	98.142	12.977	.55
14	.07	2827.174	43.252	.503	98.705	13.661	.632
15	.081	494.643	10.091	.136	98.803	13.82	.654
16	.093	209.788	5.707	8.85E-2	98.845	13.91	.668
17	.107	502.293	18.222	.326	98.945	14.198	.721
18	.124	261.533	12.653	.262	98.998	14.398	.764
19	.143	194.788	12.566	.3	99.036	14.596	.813
20	.165	50.521	4.346	.12	99.046	14.665	.832
21	.191	563.673	64.666	2.06	99.159	15.686	1.167
22	.221	22.776	3.484	.128	99.163	15.741	1.188
23	.255	0	0	0	99.163	15.741	1.188
24	.294	0	0	0	99.163	15.741	1.188
25	.34	16.675	6.05	.343	99.167	15.837	1.243
26	.392	388.865	188.126	12.304	99.244	18.908	3.244
27	.453	642.319	414.51	31.006	99.372	25.354	8.333
28	.523	727.348	625.737	54.575	99.517	35.236	17.205
29	.604	414.564	475.599	47.9	99.6	42.747	24.992
30	.698	926.32	1417.133	164.82	99.784	65.127	51.787
31	.806	1082.374	2208.14	296.569	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 5.01E 5   6332.021   615.123
FOR MEASURED DATA ONLY
GEO. MEAN: 2.32E-2   .415   .678
SPREAD FACTOR: 1.449   3.178   1.397

non

TSI DIFFERENTIAL MOBILITY PARTICLE SIZER
PULSED COMBUSTION BLANK 7/15/92
SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
          MAXIMUM DIA. MEASURED: .886 UM   START: 14:29:53
    DATE: 07-15-1992   MINIMUM DIA. MEASURED: .017 UM   END: 14:47:24

DIA CH#	DIAMETER MIDPOINT (UM)	CONCENTRATION			PERCENTAGE		
		NUMBER (#/CC)	SURFACE (UM^2/CC)	VOLUME (UM^3/CC)	NUMBER	SURFACE CUMULATIVE PERCENTAGE	VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	6.34E 4	72.841	.232	27.093	.28	7.18E-3
6	.022	6.80E 4	104.158	.385	56.145	.68	1.90E-2
7	.025	5.18E 4	105.833	.449	78.281	1.087	3.29E-2
8	.029	2.33E 4	63.587	.312	88.254	1.331	4.26E-2
9	.034	5258.24	19.076	.108	90.498	1.404	4.59E-2
10	.039	761.265	3.685	2.40E-2	90.823	1.419	4.67E-2
11	.045	369.244	2.382	1.79E-2	90.98	1.428	4.72E-2
12	.052	809.915	6.968	6.07E-2	91.326	1.454	4.91E-2
13	.06	63.194	.725	7.30E-3	91.353	1.457	4.93E-2
14	.07	371.67	5.686	6.61E-2	91.511	1.479	5.14E-2
15	.081	3394.973	69.261	.93	92.96	1.745	8.02E-2
16	.093	503.056	13.686	.212	93.175	1.798	8.67E-2
17	.107	489.206	17.748	.318	93.383	1.866	9.66E-2
18	.124	831.688	40.236	.832	93.738	2.021	.122
19	.143	215.97	13.933	.333	93.831	2.074	.133
20	.165	54.653	4.702	.13	93.854	2.092	.137
21	.191	41.333	4.742	.151	93.871	2.11	.141
22	.221	1.697	.26	9.54E-3	93.872	2.111	.142
23	.255	0	0	0	93.872	2.111	.142
24	.294	0	0	0	93.872	2.111	.142
25	.34	0	0	0	93.872	2.111	.142
26	.392	0	0	0	93.872	2.111	.142
27	.453	0	0	0	93.872	2.111	.142
28	.523	0	0	0	93.872	2.111	.142
29	.604	1090.086	1250.575	125.953	94.337	6.716	4.04
30	.698	5580.71	8537.664	992.974	96.719	39.721	34.728
31	.806	7689.941	1.56E 4	2107.031	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 2.34E 5   2.60E 4   3230.534
FOR MEASURED DATA ONLY
GEO. MEAN: 2.94E-2   .711   .76
SPREAD FACTOR: 2.395   1.566   1.134

TSI DIFFERENTIAL MOBILITY PARTICLE SIZER
NONPULSE 4/22/92 CCL4&MCB

SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
                    MAXIMUM DIA. MEASURED: .884 UM   START: 09:22:39
     DATE: 07-22-1992   MINIMUM DIA. MEASURED: .017 UM   END: 09:42:58

| | | CONCENTRATION | | | PERCENTAGE | | |
DIA CH#	DIAMETER MIDPOINT (UM)	NUMBER (#/CC)	SURFACE (UM^2/CC)	VOLUME (UM^3/CC)	NUMBER	SURFACE CUMULATIVE PERCENTAGE	VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	.39	4.47E-4	1.42E-6	1.47E-4	1.52E-5	1.00E-6
6	.022	7.88E-2	1.20E-4	4.43E-7	1.77E-4	1.93E-5	1.31E-6
7	.025	.13	2.65E-4	1.12E-6	2.26E-4	2.83E-5	2.11E-6
8	.029	0	0	0	2.26E-4	2.83E-5	2.11E-6
9	.034	0	0	0	2.26E-4	2.83E-5	2.11E-6
10	.039	3.13E 4	151.629	.992	11.875	5.155	.7
11	.045	1.25E 5	810.523	6.122	59.474	32.708	5.02
12	.052	8.46E 4	728.453	6.353	91.554	57.471	9.504
13	.06	1.30E 4	149.602	1.507	96.494	62.557	10.569
14	.07	5563.923	85.12	.99	98.602	65.45	11.266
15	.081	2111.31	43.073	.578	99.402	66.915	11.675
16	.093	504.05	13.713	.213	99.593	67.381	11.825
17	.107	216.156	7.842	.14	99.675	67.647	11.924
18	.124	164.515	7.959	.165	99.737	67.918	12.04
19	.143	145.482	9.386	.224	99.792	68.237	12.198
20	.165	81.273	6.992	.193	99.823	68.475	12.334
21	.191	7.893	.906	2.88E-2	99.826	68.505	12.355
22	.221	3.26	.499	1.83E-2	99.827	68.522	12.368
23	.255	0	0	0	99.827	68.522	12.368
24	.294	0	0	0	99.827	68.522	12.368
25	.34	0	0	0	99.827	68.522	12.368
26	.392	0	0	0	99.827	68.522	12.368
27	.453	0	0	0	99.827	68.522	12.368
28	.523	0	0	0	99.827	68.522	12.368
29	.604	2.092	2.4	.242	99.828	68.604	12.508
30	.698	4.255	6.509	.757	99.83	68.825	12.873
31	.806	449.517	917.054	123.167	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 2.05E 5   2941.06   141.689

FOR MEASURED DATA ONLY
GEO. MEAN: 4.84E-2   .121   .576
  SPREAD FACTOR: 1.2   3.643   2.45

TSI DIFFERENTIAL MOBILITY PARTICLE SIZER
"H" 7/16/92 PULSING

SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
MAXIMUM DIA. MEASURED: .986 UM   START: 09:50:33
DATE: 07-16-1992   MINIMUM DIA. MEASURED: .017 UM   END: 09:56:36

| | | CONCENTRATION | | | PERCENTAGE | | |
DIA CHN	DIAMETER MIDPOINT (UM)	NUMBER (#/CC)	SURFACE (UM^2/CC)	VOLUME (UM^3/CC)	NUMBER	SURFACE CUMULATIVE PERCENTAGE	VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	1.65E 5	187.986	.599	13.12	.869	2.37E-2
6	.022	1.60E 5	245.01	.901	25.943	2.001	7.19E-2
7	.025	1.80E 5	368.698	1.366	40.413	3.706	.147
8	.029	1.91E 5	520.663	2.554	55.737	6.112	.27
9	.034	1.67E 5	608.762	3.448	69.173	8.926	.435
10	.039	1.41E 5	685.933	4.486	80.525	12.097	.65
11	.045	1.01E 5	657.634	4.967	88.687	15.136	.898
12	.052	6.00E 4	516.343	4.503	93.493	17.523	1.104
13	.06	3.18E 4	365.348	3.68	96.043	19.212	1.281
14	.07	2.12E 4	325.046	3.78	97.744	20.714	1.462
15	.081	1.09E 4	223.044	2.996	98.619	21.745	1.606
16	.093	3926.863	106.831	1.657	98.934	22.239	1.685
17	.107	1625.818	58.91	1.055	99.064	22.511	1.736
18	.124	748.234	32.201	.749	99.123	22.679	1.772
19	.143	497.800	32.115	.767	99.164	22.827	1.809
20	.165	265.044	22.802	.629	99.185	22.932	1.839
21	.191	25.981	2.981	9.49E-2	99.187	22.946	1.844
22	.221	0	0	0	99.187	22.946	1.844
23	.255	0	0	0	99.187	22.946	1.844
24	.294	0	0	0	99.187	22.946	1.844
25	.34	0	0	0	99.187	22.946	1.844
26	.392	0	0	0	99.187	22.946	1.844
27	.453	0	0	0	99.187	22.946	1.844
28	.523	397.19	341.703	29.802	99.219	24.326	3.273
29	.604	1719.268	1972.39	198.651	99.356	33.642	12.802
30	.698	4007.176	6130.080	712.995	99.677	61.979	47.004
31	.806	4032.047	8225.778	1104.78	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 1.39E 6   2.16E 4   2084.691
FOR MEASURED DATA ONLY
GEOM. MEAN: 5.17E-2   .58   .705
GEOM. FACTOR: 1.568   3.395   1.46

TSI DIFFERENTIAL MOBILITY PARTICLE SIZER
7/29/92 NON-PULSE CCL4 LOW SR
SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
          MAXIMUM DIA. MEASURED: .986 UM   START: 09:12:08
    DATE: 07-29-1992   MINIMUM DIA. MEASURED: .017 UM   END: 09:34:03

		CONCENTRATION			PERCENTAGE		
DIA CH#	DIAMETER MIDPOINT (UM)	NUMBER (#/CC)	SURFACE (UM^2/CC)	VOLUME (UM^3/CC)	NUMBER	SURFACE CUMULATIVE PERCENTAGE	VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	2.87E 5	329.595	1.05	11.621	2.219	.675
6	.022	2.27E 5	348.402	1.281	20.833	4.564	1.499
7	.025	1.93E 5	394.727	1.676	28.66	7.221	2.578
8	.029	2.32E 5	632.355	3.101	38.062	11.477	4.573
9	.034	2.83E 5	1027.757	5.821	49.522	18.395	8.317
10	.039	2.88E 5	1396.848	9.136	61.201	27.798	14.193
11	.045	2.93E 5	1892.027	14.29	73.064	40.533	23.385
12	.052	2.59E 5	2229.128	19.442	83.546	55.538	35.89
13	.06	2.05E 5	2354.087	23.709	91.846	71.384	51.14
14	.07	1.01E 5	1546.053	17.981	95.934	81.791	62.706
15	.081	6.08E 4	1242.286	16.685	98.397	90.153	73.438
16	.093	2.60E 4	708.271	10.985	99.45	94.92	80.504
17	.107	9051.16	328.363	5.881	99.816	97.131	84.287
18	.124	2833.664	137.088	2.835	99.931	98.053	86.11
19	.143	941.203	60.72	1.45	99.969	98.462	87.043
20	.165	357.842	30.785	.849	99.983	98.669	87.589
21	.191	186.753	19.13	.609	99.99	98.798	87.981
22	.221	115.415	17.657	.649	99.995	98.917	88.399
23	.255	1.544	.315	1.33E-2	99.995	98.919	88.407
24	.294	0	0	0	99.995	98.919	88.407
25	.34	0	0	0	99.995	98.919	88.407
26	.392	0	0	0	99.995	98.919	88.407
27	.453	18.757	12.101	.914	99.996	99.001	88.995
28	.523	19.194	16.513	1.44	99.996	99.112	89.922
29	.604	34.153	39.181	3.946	99.998	99.375	92.46
30	.698	26.858	41.089	4.779	99.999	99.652	95.534
31	.806	25.342	51.7	6.944	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 2.47E 6   1.48E 4   155.468
FOR MEASURED DATA ONLY
GEO. MEAN: 3.64E-2   5.31E-2   8.04E-2
SPREAD FACTOR: 1.524   1.622   2.369

7/29/92 PULSING CCL4 LOW SR

SAMPLE # 1   AEROSOL FLOW RATE: .3 LPM   MEAS. MODE: EVERY CHNL
MAXIMUM DIA. MEASURED: .886 UM   START: 08:45:56
DATE: 07-29-1992   MINIMUM DIA. MEASURED: .017 UM   END: 09:07:59
FILE NAME : P7-29-92   RECORD: # 1

DIA CH#	DIAMETER MIDPOINT (UM)	CONCENTRATION NUMBER (#/CC)	CONCENTRATION SURFACE (UM^2/CC)	CONCENTRATION VOLUME (UM^3/CC)	PERCENTAGE NUMBER	PERCENTAGE SURFACE CUMULATIVE PERCENTAGE	PERCENTAGE VOLUME
1	.01	0	0	0	0	0	0
2	.012	0	0	0	0	0	0
3	.014	0	0	0	0	0	0
4	.017	0	0	0	0	0	0
5	.019	9.19E 4	105.491	.334	3.636	.573	.166
6	.022	2.28E 5	349.033	1.284	12.657	2.469	.803
7	.025	2.02E 5	412.022	1.75	20.642	4.707	1.67
8	.029	2.07E 5	564.63	2.769	28.849	7.774	3.042
9	.034	3.02E 5	1097.927	6.218	40.814	13.738	6.122
10	.039	3.17E 5	1536.716	10.051	53.374	22.086	11.102
11	.045	3.13E 5	2024.131	15.288	65.78	33.081	18.676
12	.052	2.83E 5	2439.694	21.278	76.993	46.334	29.219
13	.06	2.35E 5	2705.727	27.251	86.318	61.032	42.721
14	.07	1.82E 5	2784.822	32.389	93.516	76.16	58.769
15	.081	9.90E 4	2020.011	27.13	97.431	87.133	72.211
16	.093	3.96E 4	1078.069	16.72	98.998	92.989	80.495
17	.107	1.53E 4	596.688	9.97	99.604	96.013	85.435
18	.124	6295.882	304.583	6.299	99.853	97.668	88.556
19	.143	2088.986	134.768	3.219	99.936	98.4	90.151
20	.165	728.651	62.686	1.729	99.965	98.74	91.008
21	.191	379.21	43.504	1.386	99.98	98.977	91.694
22	.221	305.415	46.724	1.718	99.992	99.23	92.546
23	.255	110.516	22.546	.958	99.996	99.353	93.02
24	.294	27.571	7.501	.368	99.997	99.394	93.202
25	.34	0	0	0	99.997	99.394	93.202
26	.392	0	0	0	99.997	99.394	93.202
27	.453	0	0	0	99.997	99.394	93.202
28	.523	.354	.304	2.65E-2	99.997	99.395	93.216
29	.604	18.418	21.129	2.128	99.998	99.51	94.27
30	.698	19.896	30.438	3.54	99.999	99.675	96.024
31	.806	29.288	39.731	8.025	100	100	100
32	.931	0	0	0	0	0	0

TOTALS: 2.52E 6   1.84E 4   201.83
FOR MEASURED DATA ONLY
GEO. MEAN: 4.04E-2   5.76E-2   7.90E-2
SPREAD FACTOR: 1.509   1.571   2.067