RESULTS OF TESTING TO DEMONSTRATE THE EQUIVALENCY OF FULL-SCALE PLASMA SYSTEM TO INCINERATION FOR THE DESTRUCTION OF HAZARDOUS WASTES

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ABSTRACT

ATG Inc. (ATG) and Integrated Environmental Technology (IET), supported by Focus Environmental, jointly performed an Equivalency Test on a GASVIT™ / PEM™ system located within IET's test facility in Richland, Washington. This test demonstrated that the destruction of organic constituents in feed material by GASVIT™ / PEM™ Systems is equivalent to incineration. The results of the Equivalency Test allowed the U.S. Environmental Protection Agency to declare GASVIT™ / PEM™ technology as equivalent in performance to incineration for the destruction of organics.

The full-scale system described in the paper contains basic components that are identical in size and design to those in the commercial GASVIT™ / PEM™ unit permitted by the EPA and the State of Washington Department of Ecology for the treatment of mixed waste. Mixed waste contains both hazardous and radioactive constituents.

The commercial system has been installed at ATG's Mixed Waste Facility in Richland, Washington. The basic components include a proprietary and refractory-lined process chamber that contains plasma torches and joule heated electrodes, a high temperature solids filter, two scrubbers, a High-Efficiency Mist Eliminator (HEME), and a syngas converter. A flame-less thermal oxidizer will be used instead of a flare as the syngas converter in the commercial system.

The GASVIT™ / PEM™ plasma system destroyed more than 99.99% of the hazardous organics in the feed. Non-volatile waste residues were incorporated into a leach resistant vitrified product. Emissions of particulates, chlorine, and dioxins and furans were significantly below limits imposed by the US EPA's MACT (Maximum Achievable Control Technology) standards.

As required by the regulatory agencies in ATG's permit for the "Storage and Treatment of Mixed Waste and for Storage and Disposal of Mixed-Toxic Substances Control Act (TSCA) Regulated Polychlorinated Biphenyl (PCB) Wastes," ATG is currently conducting a demonstration test with the commercial unit. The commercial unit began operation in late 2000.

INTRODUCTION

ATG Inc. (ATG) and Integrated Environmental Technology (IET), supported by Focus Environmental, jointly performed an Equivalency Test on a GASVIT™ / PEM™ system located within IET's test facility in Richland, Washington. The objective of this Equivalency Test was to demonstrate that a GASVIT™ / PEM™ system can meet the performance standards applicable to incinerators.

The full-scale pilot system used in the Equivalency test contains basic components that are identical in size and design to those in a commercial GASVIT™ / PEM™ unit permitted by the EPA and the State of Washington Department of Ecology. The commercial system has been installed at ATG's Mixed Waste Facility, also located in Richland, Washington. In this report, the system used for the Equivalency Test is referred to as the pilot GASVIT™ / PEM™ system and the system installed at ATG's Mixed Waste Facility is referred to as the commercial GASVIT™ / PEM™ system. The only significant differences between the pilot and commercial systems are in the off-gas treatment units.

The Equivalency Test results indicate that the pilot GASVIT™ / PEM™ system destroyed the organics in the feed stream at efficiencies equal to or better than are required for incineration of hazardous wastes. Emissions data for particulate matter, hydrogen chloride/chlorine, and other organics indicate that the system will meet applicable performance requirements. Specific conclusions drawn from the Equivalency Test are as follows:

- The GASVIT™ / PEM™ system operated predictably and reliably during each Equivalency Test run, and was able to maintain operating conditions which were close to the target values stated in the Equivalency Test Plan.
- Destruction and Removal Efficiency (DRE) requirements were met for test compounds in all test runs. Minimum temperature limits and maximum combustion gas velocity indicator limits anticipated for the commercial GASVIT™ / PEM™ system are expected to yield similar results.
- Emissions data for particulate matter, hydrogen chloride, chlorine, dioxins, furans, and other organics indicate that the commercial GASVIT™ / PEM™ system emissions comply with applicable standards, including relevant MACT standards, and performance expectations.

The Equivalency Test established that the GASVIT™ / PEM™ system is capable of consistently meeting each of the performance objectives required for burning liquid hazardous waste and is equivalent to incineration in terms of organic destruction performance.

GASVIT™ / PEM™ System

A GASVIT™ / PEM system has been installed at ATG's Mixed Waste Facility to treat 1,050 tons per year of a variety of low-level mixed waste. This mixed waste has been accumulating for decades at U.S. Department of Energy and private sector facilities throughout the nation. Besides the Department of Energy, generators of mixed waste include commercial nuclear power plants, research institutions, and medical facilities. The majority of the waste will be debris and bulk solids, liquids, and metals. Examples of typical wastes are soil, filtration cakes, PCB transformer oils, solvents, lubricants used in machining uranium metals, tank residues, sheet metal, pipes, lead, personal protective equipment, spill clean up kits, and laboratory scintillation vials. The GASVIT™ process reduces the volume of waste requiring storage or disposal by approximately ten to one hundred times.

Both the pilot and commercial GASVIT™ / PEM™ systems 1) destroy toxic and non-toxic organics; 2) reduce the waste volume; and 3) vitrify the inert and, for ATG's system, radioactive residues from the destruction process. The product is a vitrified glass or rock- like material, which is highly durable and leach resistant. The by-product is a fuel gas, referred to as synthesis gas, or “syngas,” that is converted to water and carbon dioxide, a stable form, before being discharged to the atmosphere.

A GASVIT™ / PEM™ system accomplishes these functions by simultaneously gasifying and vitrifying the waste. Organics in the waste are gasified in the absence of oxygen (reducing environment) to produce a fuel gas called syngas. Simultaneously, inert wastes (metals and minerals) are melted and incorporated into a leach-resistant vitrified product. The vitrified glass meets state and federal land disposal requirements.

Unlike a combustion system that produces heat from organic materials, the gasification and vitrification system absorbs heat (an endothermic process) and requires an outside heat source. A plasma-arc provides the heat required to process wastes. Joule heating is also used to maintain the temperature of the molten bath. The thermal energy from the plasma converts the organic waste into light organics and primary elements. Steam is introduced into the chamber allowing the gasification (or steam reforming) reaction to take place. In some input wastes there is sufficient water within the matrix so that additional steam is not required.

The major subsystems of the GASVIT™ / PEM™ system are shown in Figure 1 and listed in Table I:

- Feed
- Process chamber
- Syngas processing
- Product handling

A GASVIT™ / PEM™ system has three feed subsytems. These feed subsystems are:

1) a continuous feeder for bulk solids,
2) a containerized batch feeder for heterogeneous solids, and
3) a liquid feeder.

A product handling subsystem allows the molten glass to be withdrawn and cooled to form a monolith in a receiving canister. This product is stable and highly leach-resistant. Glass forming additives are periodically introduced into the process chamber to control glass chemistry.

The syngas by-product discharged from a process chamber into a syngas processing subsystem is a mix of hydrogen, carbon monoxide, steam, acid gases, particulates, low-temperature vaporized metals, and potential PIRs (Products of Incomplete Reaction). This mixture is discharged from a process chamber at temperatures exceeding 1,000°C (1,800°F) although the reaction zone is much hotter. The syngas is then treated and cleaned and finally converted to CO_2 and water prior to being discharged to the atmosphere. The treated syngas released from a GASVIT™ / PEM™system is referred to as the “system exhaust.”

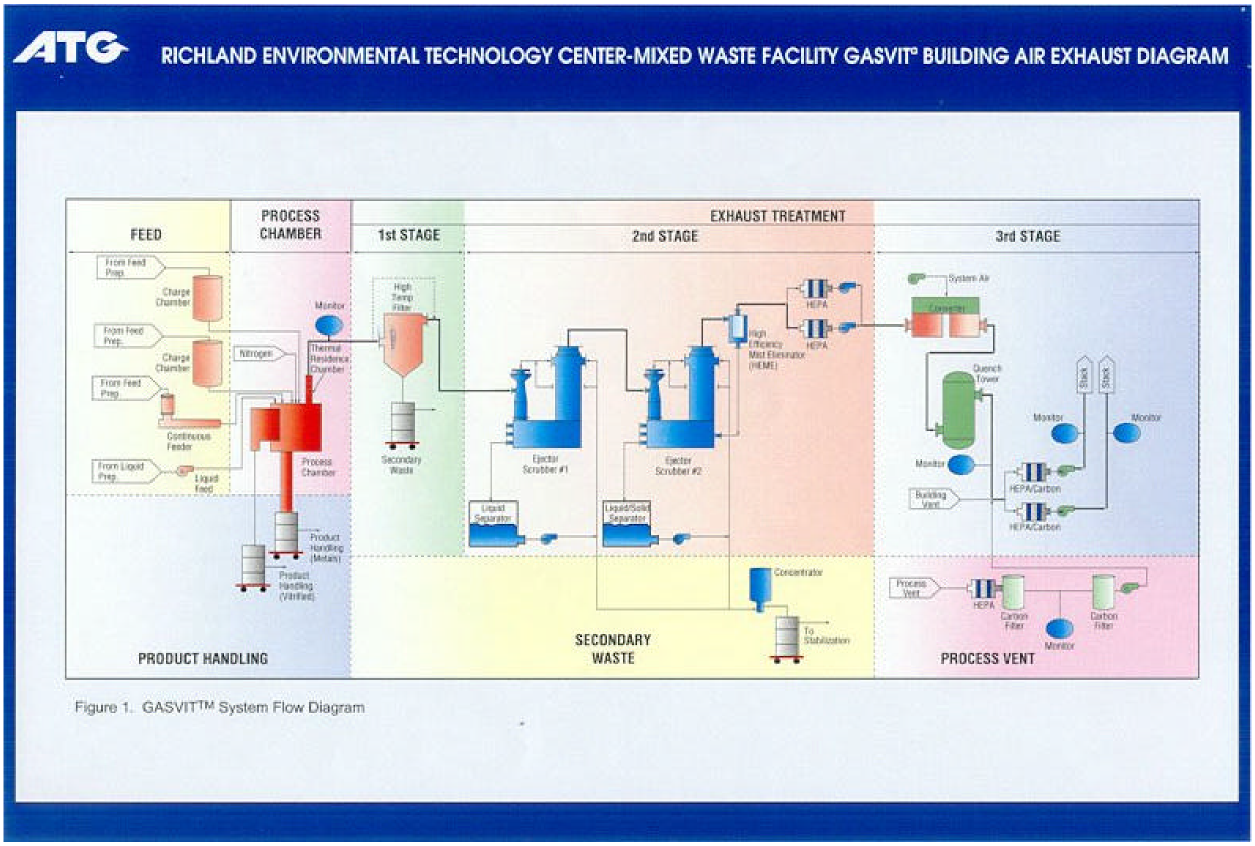

Fig. 1. GASVIT™ System Flow Diagram

Table I. Comparison of ATG and IET GASVIT™ / PEM™ Systems

Feature	**IET GASVIT™ / PEM™**	**ATG GASVIT™ / PEM™**
Feeder		
Types	1) Continuous 2) Batch 3) Liquid	1) Continuous 2) Batch 3) Liquid
Process Chamber		
Plasma Torch Capacity (Kilowatts)	1,200 DC	1,200 DC
Syngas Processing		
First Stage Syngas Processing	High Temperature Solids Filter	High Temperature Solids Filter
Second Stage Syngas Processing	Scrubber Number 1 Scrubber Number 2 HEME Induction Draft Fan	Scrubber Number 1 Scrubber Number 2 HEME Induction Draft Fan HEPA Filter Carbon Filter Booster Fan
Third Stage Syngas Processing	Flare	Thermatrix non-flammable syngas converter Water quench
Product Handling		
Joule Heating Capacity (Kilowatts)	170 AC	170 AC

A three-stage syngas processing system filters out nearly all of the syngas impurities prior to converting the purified gas into water and carbon dioxide. A first stage removes particulates larger than one micron using a high-temperature filter. Second stage scrubbers in both the pilot and commercial GASVIT™ / PEM™ systems remove acid gases (such as hydrochloric acid and hydrogen sulfide). In addition to scrubbers, the commercial GASVIT™ / PEM™ second stage syngas process also includes a high efficiency mist eliminator (HEME), a HEPA filter, and a mercury filter to remove low vapor pressure metals and particulates. In the third stage of both the pilot and commercial GASVIT™ / PEM™ systems, the scrubbed syngas is oxidized, converting the syngas to water and carbon dioxide. The ATG system oxidizes the syngas in a flameless syngas converter. The IET system oxidizes the syngas with a simple flare exhausted through a stack.

The water and carbon dioxide in the exhaust from the commercial GASVIT™ / PEM™ enters the building confinement system and is then filtered through a secondary bank of pre-filters, HEPA filters, and activated carbon filters. After carbon filtration, the gases are discharged via the building stack along with the building ventilation exhausts. Building stack radiation monitors measure critical parameters.

In comparison to the pilot GASVIT™ / PEM™ system used for this equivalency test, the commercial GASVIT™ / PEM™ system will produce an even cleaner off-gas stream in terms of emissions of gaseous byproducts, such as carbon monoxide and particulates, that result from the destruction of organics. In addition to the off-gas cleaning units included in the pilot GASVIT™ / PEM™ system, the commercial system includes HEME and HEPA filters for particulate removal and a syngas converter designed to destroy carbon monoxide.

ATG will demonstrate the performance of its enhanced off-gas treatment system during a demonstration test required by the US EPA and the Washington State Department of Ecology. The agencies granted ATG a joint permit that requires the demonstration test. The permit is for the "Storage and Treatment of Mixed Waste and for Storage and Disposal of Mixed-Toxic Substances Control Act (TSCA) Regulated Poylchlorinated Biphenyl (PCB) Wastes."

OBJECTIVES AND METHODS

A GASVIT™ / PEM™ system is defined as a Subpart X - Miscellaneous Unit, under 40 CFR 264. In accordance with Subpart X, the GASVIT™ / PEM™ system met the performance standards contained in 40 CFR 264.343, Subpart O - Incinerators that were found to be applicable by EPA Region 10, which include the following:

- A destruction and removal efficiency (DRE) of greater than or equal to 99.99% for each principal organic dangerous constituent (PODC), and a DRE of greater than or equal to 99.9999% for polychlorinated biphenyls (PCBs)
- Hydrogen chloride (HCl) emissions such that the rate of emission is no greater than the larger of either 1.8 kilograms per hour or 1% of the HCl in the stack prior to entering any pollution control equipment
- Particulate matter emissions of less than 180 milligrams per dry standard cubic meter (mg/dscm) [0.08 grains per dry standard cubic foot (gr/dscf)]

- An exhaust gas carbon monoxide (CO) concentration of less than or equal to 100 ppmv on an hourly rolling average, as referenced in "Guidance on PIC Controls for Hazardous Waste Incinerators, Volume V of the Hazardous Waste Incineration Series, EPA/530-SW-90-040 (incorporated via the RCRA omnibus provision).

In addition, emissions data for dioxin/furan and other organic emissions data were collected as a preliminary indication of system performance

A comparison of the key components employed by the pilot and commercial GASVIT™ / PEM™ systems was presented in

Table I above. The commercial system has an additional HEPA filter and an activated carbon bed filter in its syngas processing subsystem. The commercial GASVIT™ / PEM™ system uses a flameless syngas converter and carbon adsorption for final emissions control. These converter and carbon units are expected to provide emissions performance superior to that of the simple flare included in the pilot GASVIT™ / PEM™ system.

The Equivalency Test was conducted under the following conditions:

1. maximum system gas velocity (minimum gas residence time),
2. minimum thermal residence chamber temperature, and
3. liquid feed.

These conditions represent a "worst-case" for organic destruction. Liquid feed is worst case as liquid constituents may easily volatilize and move out of the process chamber before they react.

During the Equivalency Test, a sample was taken from each drum of liquid fed during a run. The samples were analyzed using SW-846 Method 826. The liquid feed rates and the respective Principal Organic Dangerous Constituents (PODCs), for example toluene, were used to calculate the total PODCs feed rates during each test run. PODC emission rates were determined using a modification of SW-846 Method 0031 and SW-846 Method 0023A.

Stack gas sampling and monitoring protocols for the Equivalency Test are summarized below.

- Stack gas target volatile organics using SW-846 Method 0031
- Stack gas particulate matter, HCl and Cl_2 using SW-846 Method 0050
- Stack gas PAHs (Polycyclic Aromatic Hydrocarbons), PCBs (PolyChlorinated Biphenyls) and dioxins and furans using an adaptation of SW-846 Method 0023A.

The liquid waste feed material was a blend of organic liquid carrier fluid and other organic surrogate materials prepared prior to the Equivalency Test to provide the desired feed characteristics. PODCs and PCBs were in the liquid waste feed as it was pumped into the process chamber. During Test Condition 1, grab samples of the liquid waste feed were collected for every batch for every run. The samples were analyzed for target volatiles and PODCs SW-846 Method 8260.

During the Equivalency Test, the stack gases were sampled and analyzed for a variety of organic compounds as follows:

- Target Volatile Organics and Tentatively Identified Compounds (TICs)
- Semivolatile Organics, PAHs and PCBs
- Dioxins and Furans.

Volatile Organics

SW-846 Method 0031 (SMVOC) was used to determine the emission rates of target volatile organic compounds and volatile TICs.

Target Semivolatile Organics and TICs

An adaptation of SW-846 Method 0023A was used to sample the stack gases for PAHs, PCBs, dioxins, and furans.

Dioxins and Furans

Stack gases were sampled for dioxin and furan emissions. Analyses were performed to identify the total mass of the tetra- through octa-chlorinated dioxins and furans congeners, as well as the mass of each individual 2,3,7,8-substituted dioxin and furan congener. In order to evaluate the potential risk posed by emissions of a variety of dioxin and furan compounds, each of the 17 congeners having chlorine atoms at the “2”, “3”, “7”, and “8” positions on the molecule is assigned a "toxic equivalence factor," which is used to equate the toxicity of that compound to the toxicity of 2,3,7,8-TCDD. Analytical results were obtained for each of the 2,3,7,8-substituted dioxin and furan isomers, and their corresponding emissions were expressed as 2,3,7,8-TCDD toxic equivalents.

Grab samples of the combined scrubber blowdown stream was collected at the end of each run. Volatile organic samples were collected in separate VOA vials and semivolatile organic samples were collected in 500 ml amber bottles. The samples were analyzed for target volatiles and PAHs using SW-846 Method 8260 and CARB 429, PCBs using EPA Method 1668.

Equivalency Test Implementation Summary

The Equivalency Test was conducted on April 4 through 5, 2000. One test condition at low temperature and high gas flow rate was conducted to demonstrate “worst case” conditions for organic destruction. The test condition was comprised of three sampling runs.

The operating conditions for the sampling runs are described in Table II. With one exception, the conditions are similar to those expected in the commercial GASVIT™ / PEM ™ system. The pH in the secondary scrubber of the commercial system will be maintained above 7, a more favorable condition for removing chlorine. Temperatures rose gradually throughout the runs, as shown for the four and one-half hour Run 1 in Figure 2. Run periods and profiles for other runs were similar.

Table II. Operating Conditions (a)

Parameter	Units	Run 1	Run 2	Run 3
Plenum Temperature	°C (°F)	1,156 (2,113)	1,139 (2,080)	1,215 (2,217)
Off Gas Temperature	°C (°F)	816 (1,501)	806 (1,483)	659 (1,218)
Baghouse Temperature	°C (°F)	191 (376)	157 (315)	184 (363)
TRC Temperature	°C (°F)	803 (1,477)	723 (1,333)	863 (1,585)
Primary Scrubber	pH	1.6	2.3	8.9
Primary Scrubber	MS/cm	42	41	40
Off-Gas Flow Rate	Scfm	137	136	151
Secondary Scrubber	pH	3.3	1.64	1.1

(a) One-minute rolling averages

Sample Collection

Liquid feed and stack gas samples were samples collected and analyzed as part of the Equivalency Test program. Sampling QA/QC objectives are considered to be met if sampling activities follow the standard methods described in the Equivalency Test Plan and QA/QC plan. During this Equivalency Test, sampling activities followed the prescribed procedures.

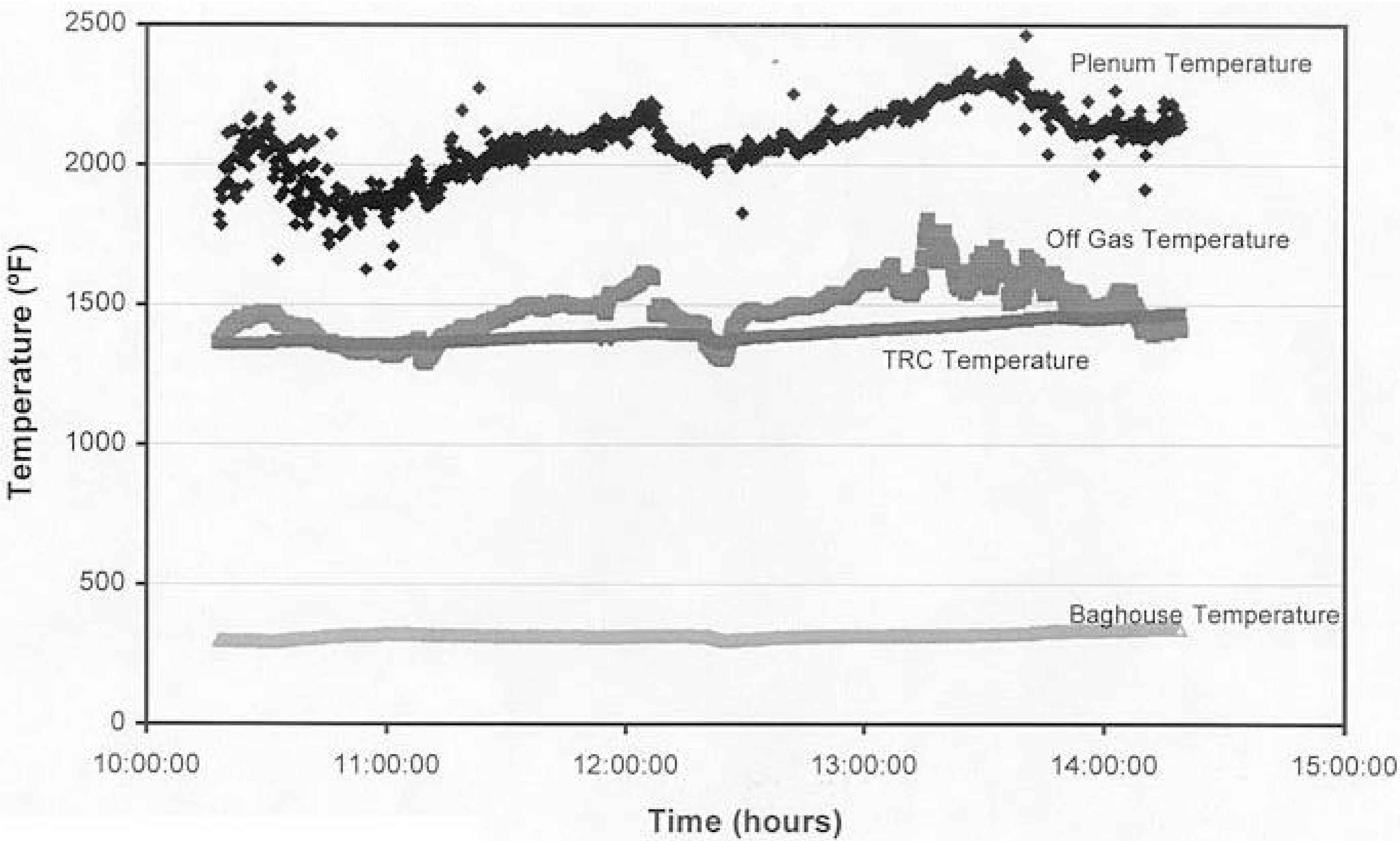

Fig. 2. Temperature Trends

RESULTS AND DISCUSSION

The destruction and removal efficiencies and emissions measured during the equivalency test are summarized in **Table** III. The table shows that regulatory standard, for example 99.99% destruction of hydrocarbons, were met for all runs.

Table III. Comparison of Equivalency Standards with GASVIT™/PEM System Destruction and Removal Efficiencies and Emissions

Parameter	**Units**	**Standard**	**Run 1**	**Run 2**	**Run 3**
DRE					
Monochlorobenzene	%	≥ 99.99	> 99.9999628	> 99.9999628	> 99.9999659
Toluene	%	≥ 99.99	> 99.9999527	> 99.9999547	> 99.9999572
Benzene	%	>99.99	>99.999959	>99.999945	>99.999965
Napthalene	%	>99.99	>99.9996615	-	-
Tetrachloroethylene	%	>99.99	>99.99991	>99.999992	>99.999992
Particulates (a)	gr/dscf	<0.015	0.00160	0.000996	0.000747
HCl & Chlorine (a,b)	Ppm	<21	<5.4	<14	<0.33
2,3,7,8-TCDD TEQ (a)	ng/dscm	<0.20	0.0054	0.000028	0.000046

Notes:

(a) Standard conditions are 68°F, 29.92 in. Hg (20°C, 760 mm Hg)
(b) Expressed as hydrogen chloride equivalents
(c) Equivalency standards only apply directly to the PODCs monochlorobenzene and toluene

Destruction and Removal Efficiency

The GASVIT™/PEM system achieved a destruction and removal efficiency (DRE) of greater than or equal to 99.99% for each of the two principal organic dangerous constituents (PODCs) monochlorobenzene and toluene. Destruction and removal efficiencies for these compounds are listed in Table III.

Organic Compound Emissions

Three organic compounds present in the liquid feed were not detected in the emissions during any of the three runs. Benzene, toluene, and tetrachloroethylene all had DRE's of 99.9999% (six 9s) or greater. DRE's for these compounds were measured in addition to those for the PODCs monochlorobenzene and toluene, measurement of which was required to demonstrate equivalency.

Particulate Emissions

Particulate matter concentrations and emission rates are also shown in Table III. Total particulate matter concentrations met the applicable emission standard by a significant margin.

Hydrogen Chloride and Chlorine Emissions

The total stack gas concentration of hydrogen chloride and chlorine, expressed as hydrogen chloride equivalents in Table III, was significantly below the applicable emission standard.

Dioxin and Furan Emissions

Extremely low concentrations of a few dioxins and furans were detected in the emissions. No dioxins or furans with a toxicity equivalency factor greater than 0.1 were present at concentrations greater than the corresponding detection limit. The most toxic dioxins and furans have a toxicity equivalent of 1. Assuming all undetected dioxins and furans were present at their detection limit, the total mass emission rate of all dioxins and furans tested for varied from 7.59 E-08 to 6.47 E-07 between the three runs. The total toxicity equivalent emissions were very low, varying from 7.59 E-11 to 1.61 E-08. The analytical method used to detect the dioxins and furans, GC/MS Method (SW846-8290) is the most sensitive method approved by the EPA.

CONCLUSION

The Equivalency Test demonstrated that the destruction of organic constituents in feed material by GASVIT™ / PEM™ Systems is equivalent to incineration. The test results support a petition to the EPA to declare GASVIT™ / PEM™ technology as equivalent in performance to incineration for the destruction of organics. Approval of such a petition would reduce the analytical requirements for disposal of the glass currently being produced by the commercial GASVIT™ / PEM™ system operating at ATG's Richland Mixed Waste Facility.

REFERENCES

- USEPA SW-846, Test Methods for Evaluating Solid Waste
- 40 CFR 266 Appendix IX, "Performance Specifications for Continuous Emission Monitoring Systems"
- USEPA QAMS-005/80, Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans
- EPA/625/6-89/023, Quality Assurance/Quality Control (QA/QC) Procedures for Hazardous Waste Incineration
- EPA/600/4-77-027b, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods
- 40 CFR 60 Appendix A, "Test Methods and Procedures, New Source Performance Standards"
- 40 CFR 61 Appendix B, "Test Methods".