Solvated Electron Technology TM Non-Thermal Alternative to Waste Incineration - 8461

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ABSTRACT

Solvated Electron Technology (SET™) is a patented non-thermal alternative to incineration for treating Toxic Substances Control Act (TSCA) and other mixed waste by destroying organic hazardous components. SET™ is a treatment process that destroys the hazardous components in mixed waste by chemical reduction. The residual material meets land disposal restriction (LDR) and TSCA requirements for disposal. In application, contaminated materials are placed into a treatment cell and mixed with the solvated electron solution. In the case of PCBs or other halogenated contaminants, chemical reactions strip the halogen ions from the chain or aromatic ring producing sodium chloride and high molecular weight hydrocarbons. At the end of the reaction, ammonia within the treatment cell is removed and recycled. The reaction products (such as sodium salts) produced in the process remain with the matrix.

The SET™ process is 99.999% effective in destroying: polychlorinated biphenyls (PCBs); trichloroethane (TCA) and trichloroethene (TCE); dioxins; polycyclic aromatic hydrocarbons (PAHs); benzene, toluene, xylene (BTX); pesticides; fungicides; herbicides; chlorofluorocarbons (CFCs); hydrochlorofluorocarbons (HCFCs), explosives and chemical-warfare agents; and has successfully destroyed many of the wastes listed in 40 Code of Federal Regulations (CFR) 261.

In September 2007, U.S. Environmental Protection Agency (EPA) issued a Research and Development permit for SET for chemical destruction of “pure” Pyranol, which is 60% PCBs. These tests were completed in November 2007. SET™ is recognized by EPA as a non-thermal process equivalent to incineration and three SET™ systems have been permitted by EPA as commercial mobile PCB destruction units. This paper describes in detail the results of select bench-, pilot-, and commercial-scale treatment of hazardous and mixed wastes for EPA, Department of Energy (DOE), and the Department of Defense(DoD), and the applicability of SET™ to currently problematic waste streams that have very limited treatment alternatives.

OVERVIEW OF SET

SET™ is based on a scientific phenomenon; alkali metals dissolved in ammonia create a solvated electron solution. As solvated (free) electrons are formed in the solution, they produce one of the strongest chemical reducing agents known. They react with most organic molecules including hazardous materials. The technology utilizes this chemistry in a simple, safe, non-thermal process that has proven effective on commercial projects in hazardous and radioactive environments.

SET™ operates as a non-thermal destruction process under low pressure. The process occurs in a closed system producing no hazardous off-gases and no regulated by-products such as dioxins or furans or their precursors. Advantages of SET™ include:

- Organic contaminants are destroyed, not just removed, diluted or concentrated.
- Operates as a closed system – produces no regulated secondary wastes.
- Holds an EPA permit for PCB destruction.
- Operates at ambient temperatures (70°F).
- Portable and sets up quickly in less than 4000 square feet of space.
- Scalable to accommodate any size waste stream.
- Requires minimal amounts of power, water and infrastructure.
- Applicable to heterogeneous waste streams in all phases.

SET™ is effective in destroying hazardous, toxic and halogenated compounds including PCBs. Halogenated compounds are organic and contain chlorine, fluorine or iodine. Whether found in soils, oils, sludge, sediments, metals, concrete, liquids or other media, SET™ can safely transform halogenated compounds into non-toxic, unregulated material suitable for conventional disposal. Hazardous waste is placed into a treatment cell and mixed with the solvated electron solution. In the case of PCBs and other halogenated compounds, chemical reaction strips the halogen ions from the aromatic ring producing sodium chloride and heavy hydrocarbons. At the end of the reaction, ammonia in the treatment cell is removed and recycled. The reaction products, such as sodium chloride, remain with the matrix.

The destructive abilities of SET™ have been demonstrated to EPA, DOE, DoD and private sector clients in commercial operations, and in numerous pilot and treatability projects. These projects have been performed in both radioactive and non-radioactive environments.

The Commodore SET™ process has been field proven in the destruction of PCBs to less than 1 part per million (ppm). It has met stringent design and operational safety requirements, proven its versatility on heterogeneous waste streams and done so in a simple, safe, non-thermal treatment process.

HISTORY AND MATURITY OF SET

In the 19^{th} century chemists discovered that some metals would readily dissolve in certain liquids. The metals include sodium, lithium, calcium, and potassium and the dissolving liquid is ammonia (which liquefies at -27° F). As the metals dissolve, the liquid turns dark blue and the conductivity rises dramatically; the solution will conduct electricity nearly as well as a pure metal.

For decades this phenomenon has been called solvated electrons, since the dissolved metal releases electrons to the solution in huge numbers. These electrons (free radicals) are the most powerful reducing agents known, quickly reacting with many compounds. For instance, when carbon tetrachloride is dripped into a solvated electron solution, the chlorine is stripped from the carbon, forming a benign salt. Although possible useful applications have long been recognized, until recently, solvated electron solutions have remained a laboratory curiosity.

In the early 1980s, research into application of solvated electron solutions to environmental problems began. Commodore Applied Technologies, Inc. (Commodore) acquired the research in 1993. Since then, Commodore has invested additional resources in the technology, developing it carefully and methodically into commercial application.

The success of pilot scale tests led Commodore to apply for an EPA nationwide permit for chemical destruction of PCBs. The demonstration test was completed in August 1995, and Commodore was issued a mobile permit for nationwide operations. The permit authorized treatment of soils at contamination levels greater than 1,000 ppm PCBs, and also authorizes treatment of miscellaneous metallic materials. Beyond treating PCB contaminated soils (containing various water, clay, and other constituents), Commodore has also treated PCB contaminated soils received from potential remediation sites. Commodore's initial EPA permit was the first (and only) to be issued for nationwide use as a totally enclosed, non-thermal chemical destruction process.

In early 1996, Commodore began construction of a commercial scale SET™ system, the L1200. This machine is capable of treating 1200 gallons of contaminated liquids per day. In July, 1997, this machine was demonstrated to EPA as a chemical destruction system for PCBs. In the tests conducted, waste oils contaminated with PCBs at levels exceeding 20,000 ppm were consistently rendered non-detectable for PCBs. The nationwide operating permit for this machine is currently in effect.

In 1999, Commodore introduced its largest current commercial SET™ system, the S-10, capable of treating various matrices in batch sizes of up to 3,500 pounds with throughputs up to 1 ton per hour. Commodore also built a mobile system capable of treating all matrices up to 500 pound batches, the SL-2. It was specifically designed as a stand-alone, skid-mounted system, requiring only electrical hookup for operation. It can be shipped in sea land containers on a single tractor trailer. This system has operated at two rad/RCRA/TSCA-permitted facilities, treating low-level mixed wastes. This system will be used at the Portsmouth DOE site in 2008.

In October 2007, Commodore performed a treatability study using SET™ to chemically destruct PCBs in an oil matrix containing PCB Aroclors™ 1254 and 1260 dissolved in paraffin-based oil (Pyranol). The PCB content of the matrix was approximately 60%, or 600,000 ppm. The first batch of Pyranol was processed on October 15, and the last test run was performed on October 30 (run number 15). Both glassware (Erlenmeyer flasks - 2,000 ml) and a small pressurized SET™ system (R2D2) were used for the tests. The flasks normally treated 10 gram batches of

Pyranol, while the R2D2 system treated from 45 to 75 grams. Post-treatment PCB levels ranged from a high of 4,200 ppm (an intentional "under kill") to less than 0.5 ppm (at a method detection limit of 0.5 ppm). Six of the test runs demonstrated post-treatment PCB levels less than 1.0 ppm at an MDL of at least 1.0 ppm, thereby meeting contract requirements for "successful treatment." The post-treated material was a dry solid that resembles soil.

The Pyranol treatability study verified the ability of the SET™ process to destroy PCBs at 600,000 ppm to post-treatment levels less than 1 ppm. The pertinent test results documenting the successful tests are summarized in Table I. No major problems were encountered and no major deviations from the test plan occurred during the demonstration test. Treatability study results are summarized below.

Table I. Pyranol Demonstration Test Results Runs 9, 10, and 11

	Run 9	**Run 10**	**Run 11**
Date and Time Test Begun	10/22/07 at 08:55	10/22/07 at 12:55	10/22/07 at 15:45
Date and Time Test Ended	10/22/07 at 12:30	10/22/07 at 15:30	10/22/07 at 17:15
Operating parameters:			
System	R2D2	Glass	Glass
Batch type	Liquid	Liquid	Liquid
Batch characteristics	See R&D permit	See R&D permit	See R&D permit
Batch mass waste feed (grams)	34	8.5	10
PCB concentration in feed (ppm)	600,000	600,000	600,000
Ammonia volume (ml)	3,000	800	800
Sodium mass (grams)	46	10	10.9
Sampling/Analysis Results:			
Final PCB concentration	< 0.5	< 0.5	< 0.5

Fig. 1. SET™ S-10 in Operation

ENVIRONMENTAL, SAFETY AND HEALTH CONSIDERATIONS

SET™ systems present less risk than other methods for treating mixed low-level waste (MLLW), particularly incineration. Most SET™ operations are performed under moderate pressures and temperatures. Large amounts of ammonia and sodium are safely handled throughout the world every day by trained personnel, in quantities much greater than those needed for SET™ systems. Anhydrous ammonia is widely used as an agricultural fertilizer and a refrigerant. This material is transported in compliance with Department of Transportation (DOT) regulations in tank trucks, and is either transferred to an ammonia tank or ammonia cylinders are used. Ammonia is used in liquid form, and SET™ equipment is designed to accommodate the vapor pressure required to maintain this state (temperature dependent - 114 psig at 80 ºF). Ammonia is recovered by distillation for reuse. The ammonia vapors are recompressed and cooled to re-liquefy by the ammonia recovery subsystem.

Three Concerns with Human Exposure to Ammonia

1. Inhalation of the gas at higher than permissible exposure levels (50 ppm) can cause severe respiratory distress.
2. Ammonia reacts with water to form a basic compound, exposure to the eyes, skin, and mucus membranes can cause chemical burns.
3. In liquid state at ambient pressures, ammonia is very cold (-30 F) and can freeze tissues.

Metallic sodium is the reactant in the SET™ process. It is received in cast form, either in 55-gallon drums or larger shipping containers, and is melted by a SET™ subsystem and dripped or pumped into liquid ammonia to create a solvated solution. After dissolving in ammonia, the reactive properties of sodium are not as aggressive as in its metallic form.

Sodium reacts violently with water to produce hydrogen gas and sodium hydroxide, a basic compound. Hydrogen is highly flammable. Sodium can also be ignited, and sodium fires must be extinguished by blanketing to exclude oxygen.

All of the hazards described above are mitigated by training, engineering controls, and personal protective equipment. Commodore has never experienced a reportable injury during SET™ waste treatment operations.

Table II. Summary of Key Characteristics

Criteria	Commercially Operating and Available	Safe, Reliable Operation	Efficient Destruction of PCBs and Other Organics	Non-Thermal Operation
Environmental Safety And Health	Designed & operationally proven IAW 49 CFR 1910.119 process hazards analysis	>10,000 hours of safe operations with no single lost time accident	Utilizes sized batch of solvated electron solution to control reaction and achieve PCB destruction	Operates at 70°F as a closed system to enhance worker and environmental safety
Stakeholder And Regulatory Interests	SET has operated in 9 states to date with no opposition	SET has met EPA national contingency plan criteria	SET produces no hazardous by-products or secondary waste during treatment	No air permit is required
Functional And Technical Performance	Treated 20 material types, 51 chemicals and hundreds of tons of material	Unit operation design and batch mode add to safety in operations	EPA permit first issued in 1996 for PCB destruction equivalent to incineration	Almost any heterogeneous matrix can be treated
Operational Reliability	Over 10,000 hours of SET operations in 9 states including Hawaii	Over 14 months of field operation with one SET unit on mixed waste	All mixed and hazardous waste treated met regulatory requirements for ultimate disposal	Non-thermal operation reduces stress and maintenance on equipment
Pre- And Post-Treatment	Only sizing required prior to introduction to equipment	Heterogeneous waste streams acceptable reducing need to segregate waste	Post-treatment will require only pH adjustment in most instances	Ammonia is recycled for reuse on the next batch with no post-treatment needed
Economic Viability	Currently operating on a competitively bid and won project for the DOD	Simple in design, low cost in construction and field proven on reliability	A cold solvated solution used for destruction yielding low operating costs	More cost-effective than thermal
Maturity	Mixed waste treated at 3 locations and 3 states; currently in operation	Five commercial units in operation with only 3-6 months lead needed for new units	SET equipment was decontaminated after 3 mixed waste projects for free release	Ammonia recovery systems have been in use for decades for refrigeration

CHEMISTRY AND PROCESS SCHEMATIC

The chemically destructive process relies on the ability of sodium to dissolve in liquid anhydrous ammonia, creating a solvated solution of sodium ions and free electrons. This solution is the most chemically reductive of those readily created in laboratories, and is in essence the antithesis of oxidation reactions, which generally rely on heat to destruct compounds. Chemically, for PCBs, the reaction proceeds as follows:

$$NH3 + Na \rightarrow NH3 + Na+ + e- \qquad \text{(Eq. 1)}$$

Note that the ammonia serves as a recyclable solvent, and is not a reagent in any reactions involving the SET solution. The solution's application to a PCB molecule (Aroclor™ 1260 depicted, which is approximately 60% chlorine by mass) results in the following:

$$NH_3 + 5Na^+ + e^- + C_{12}H_5Cl_5 \rightarrow NH_3 + 5NaCl + C_{12}H_{10} \qquad \text{(Eq. 2)}$$

The chlorine cleavage sites provide opportunities for the stripped PCB molecule to chain into various unregulated compounds, most of which are solid. This chaining phenomenon causes the relatively fluid (consistency of cooking oil) target material to exit from the process with soil-like properties.

Commodore has developed and commercialized several SET™ process variations depending on the nature of the material being treated. However, all process variations include the basic process steps presented in the schematic of the SET process given in Figure 2. Material to be treated is first placed in the treatment cell and anhydrous ammonia is added to create the slurry. At the same time, in a separate vessel, elemental sodium is dissolved in anhydrous ammonia to create the solvated electron solution. The solvated electron solution is then added to the ammonia/matrix slurry in the treatment cell. Upon mixing, the reaction is complete because the destruction reaction is very fast and is essentially diffusion controlled. Ammonia is then removed from the treatment cell and recovered for reuse through the ammonia recovery system. Ammonia vapors are passed through a scrubber and high efficiency particulate air (HEPA) filter to ensure no radioactive species are released during the process of opening valves. At this point, organics have been destroyed, and with pH adjustment, the product and is suitable for disposal.

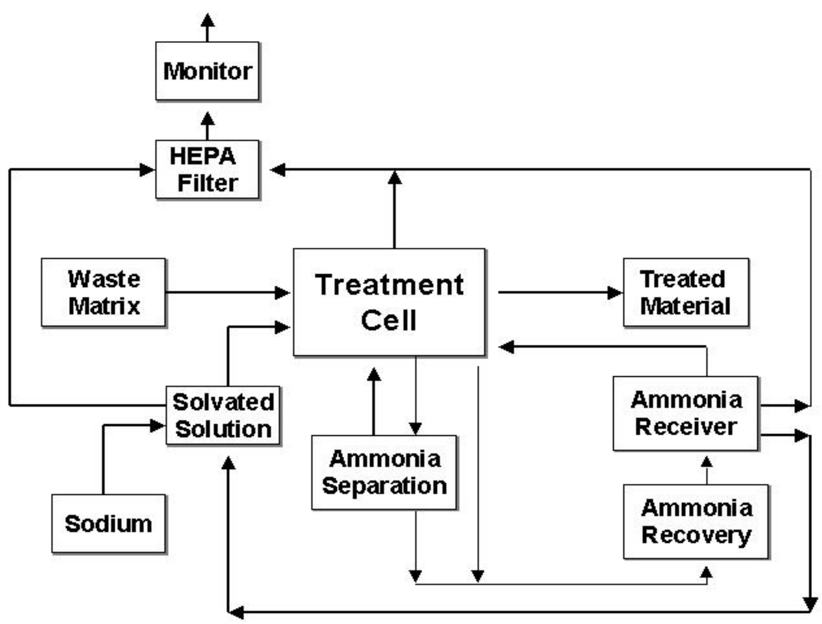

Fig. 2. SET Process

PROCESS DESCRIPTION

Load Waste
Waste may be pre-treated (discussed in a later section) by any of several processes such as shredding. Waste is then placed in the treatment cell.

Create Ammonia Slurry
After loading the treatment cell, the cell is closed to the atmosphere and ammonia is pumped from the ammonia receiver into the treatment cell. Stirring of the waste ammonia slurry at approximately 70°F begins and progresses for at least 15 minutes. The purpose of this step is to extract the organic contaminant such as PCBs into the ammonia.

Prepare Solvated Electron Solution
Ammonia is added to the solvate tank and the tank agitator is turned on. Molten sodium is pumped into the solvate tank from the sodium reservoir. The solvate tank is stirred for approximately 15 minutes to ensure complete dissolving of the sodium. At this point, sodium metal no longer exists. Rather, the solution is now a negatively charged free electron and a positively charged sodium cation identical to the cation in sodium chloride.

Destroy Organic Contaminant
The solvated electrons can now be pumped from the solvate tank into the treatment cell. The chemical reaction between the solvated electron and the contaminant such as the PCB molecule takes place almost instantly. Once the solvated electron and the PCB molecule come in contact, the reaction is complete.

Recover Ammonia
Hot water or steam is circulated through the jacket of the treatment cell. The warmed ammonia is subsequently evaporated through the ammonia compressor and heat exchanger back to the ammonia receiver.

pH Adjust Waste
At the end of the SET reaction, the matrix may have a high pH which requires adjustment prior to disposal. A dilute acid solution is made in a separate tank using water and acid. When all the ammonia is removed, the treatment cell is opened to the atmosphere through the HEPA Filter. The dilute acid is pumped from the tank to the treatment cell and the matrix is stirred for approximately 5 minutes.

Remove Waste from Treatment Cell
The treated material is removed from the treatment cell by opening the bottom valve and dropping the treated material into a container such as a drum for final disposal.

Ship Waste for Final Disposal
SET™-treated waste is suitable for shipment using 55-gallon drums or larger containers. It is no longer RCRA hazardous material in regards to organic compounds or pH. If the untreated waste is MLLW, it is shipped according to DOT regulations for radioactive materials.

APPLICATION OF SET TO DIVERSE WASTE TYPES

Commodore's SET™ equipment has successfully remediated a wide variety of materials contaminated by toxic substances. Almost any matrix can be treated using the non-thermal SET™ process, including heterogeneous waste streams. The process is capable of destroying a wide range of hazardous organics in a mixture of matrices at the same time. Soil, rock, cement, personal protective equipment and absorbents can be treated together at the same time. Numerous remediation projects using solvated electrons have been completed including in-house and on-site projects. Below is a list of waste media treated to date:

- Soils - sand, clay, sediment
- Filter media
- Oils and solvents
- Glass
- Organics and organic debris
- Organic liquids
- Aqueous liquids
- Plastics
- Absorbents
- Metals, metal parts, tools, metal debris
- Sludges
- Wood and sawdust
- Carbon or graphite
- Rags
- Paper and cardboard
- Sandblast residue
- Personal Protective Equipment
- Pipe
- Paint chips/sludge
- Electric cable
- Rubber
- Fiberglass
- Rubber
- Concrete and brick
- Rocks and gravel

Contaminated Solids

Table III includes field data for treatment of diverse waste streams. Metal surfaces are the easiest materials to remediate. Absorbing matrices such as soils and corncobs are more complex and require appropriate amounts of sodium for processing. Adjustments in the sodium to matrix ratio allow any of these matrices to be treated. The organic contaminant must be extracted into the liquid ammonia for destruction to take place. Fortunately, most halogenated and hazardous organics have a reasonable solubility in liquid ammonia. Shredding or grinding may be required for size reduction. The treatment cell can accomplish grinding but shredding must be accomplished outside the treatment cell. Extraction is accomplished in the treatment cell by mixing in the presence of the ammonia.

Table III. Destruction of Organics in Various Solid Materials

Source of Material	Analyte	Material Type	Pre Treatment (mg/kg)	Post-Treatment (mg/kg)
Harrisburg, PA	PCB	Sand, clay	777	<1.0
Los Alamos, NM	PCB	Sand, silt, clay	77	<2.0
New York	PCB	Sand, silt	1250	<2.0
Monroe, LA	PCB	Sand, silt, clay	8.8	<1.0
Hawaii	PCB	Volcanic Soil	102	0.2
North Island Naval Shipyard	PCB	Activated Carbon	512	0.93

ConTech	PCB	Solid Resin	1212	0.5
New Bedford, MA	PCB	Sludge	32,800	1.3
New Bedford, MA	Dioxin	Sludge	.04	ND
Dahlgren, VA	DDD	Clay	15	<. 02
Weldon Spring, MO	TCE	Corn cob	6,400	<0.5
Weldon Spring, MO	PCB	Metal Capacitors	5.6	<0.2
Los Alamos	RDX	Soil	3850	<1.0
Eastern Utility	TCE	Soil	48,000	0.5

Liquids

The SET™ process has been also applied to many different liquid waste streams including: oils, aqueous sludges and neat liquid waste. Liquid wastes with contaminated concentrations varying from 100% to low ppm levels have been treated. Table IV contains representative data for the treatment of various liquid waste streams.

Table IV. Destruction of Halogenated Materials in Liquids

Material	Analyte	Pre-Treatment (mg/L)	Post-treatment (mg/L)
Used Motor oil	PCB	23,339	<1.0
Transformer oil	PCB	509,000	20*
Mineral Oil	PCB	5000	<0.5
Hexane	PCB	100,000	0.5
Aqueous sludge	Freon 113	276	ND
Aqueous sludge	TCE	262	ND
Oil	CCl	200,000	<0.5
Refrigerant	R 23	999,999	ND
Oil	Dioxin	0.4	.000002
Oil	Malathion	900,000	ND

Liquids are some of the more easily handled materials. Post treatment levels below 1 ppm are achieved. Typically, the solvated electron solution is formed first and the liquid is pumped into the solvated electron solution until the solvated electron solution is depleted. Thus, the appropriate kinetics can easily be controlled.

Mixed Wastes

In the case of soils containing low-level radioactive components, in conjunction with halogenated organic compounds, the SET™ process can successfully destroy the halogenated organic component without oxidizing or volatilizing the metallic component. The radioactive species remains in the matrix for subsequent disposal.

Table V. Destruction of Halocarbons in Various Radioactive Materials

Analyte	Site	Material	Pre-Treatment (mg/kg)	Destruction Efficiency (%)
PCB	Weldon Spring, MO	Shredded Corn Cobs	1270	99.8
PCB	Weldon Spring, MO	Un–shredded Corn cobs	944	97.4
PCB	Weldon Spring, MO	Transformer Capacitor parts	6	99.8
TCE	NE Utility	Soil	48,000	99.99
Chlorobenzene	NE Utility	Soil	360	99.99

Methylene chloride	Mid West Utility	Paint sludge	10,000	99.99
Freon 113	MD Nuclear	Grease	32,070	99.99
Freon 113	DOE Site	Aqueous (70 % H2O)	652	<0.1

Destruction Efficiency

The SET™ process has been designed to economically accommodate a wide range of destruction efficiencies depending on the client needs. This is accomplished by slight modifications in process variables. Destruction efficiencies in excess of 99.99 % have been achieved for many different organic contaminants. Table VI lists destruction efficiencies obtained for selected materials contaminated with PCBs. In some cases a client needs to achieve a PCB cleanup standard of below 1 ppm, while in others a clean up goal of 25 ppm is required. Commodore has been effective in economically meeting regulatory needs of its clients.

Table VI. Destruction Efficiencies of PCB Contaminated Materials

Material Source	**Type**	**Pre- Treatment (mg/kg)**	**Post-Treatment (mg/kg)**	**Destruction Efficiency %**
Harrisburg, PA	Sand, clay	777	<1.0	99.87
Los Alamos, NM	Sand, silt, clay	77	<2.0	97.4
New York	Sand, silt	1250	<2.0	99.84
Monroe, LA	Sand, silt, clay	8.8	<1.0	88.6
Hawaii	Volcanic soil	102	0.2	99.80
Hawaii	Volcanic soil	2310	2.0	99.91
Hawaii	Volcanic soil	6020	11	99.82
New Bedford, MA	Sludge	32,800	1.3	99.996
Used	Motor Oil	23,339	<1.0	99.995
Transformer	Oil	509,000	20	99.996
	Hexane	100,000	0.5	99.9995
Weldon Spring, MO	Capacitors	5.6	<0.2	96.4
Marengo, Ohio	Metal Surface	26,000[a]	1.1[a]	99.995
North Island Shipyard	Charcoal	512	.93	99.81
Weldon Spring	Corn Cobs	6500	0.5	99.992

[a]micrograms/100 cm2

Volume Reduction

Considerable volume reduction is accomplished through the action of the rotator paddles in the treatment cell. These paddles reduce the volume of many materials such as personal protective equipment and absorbent materials. By creating a smaller particle size, the solid matrix being treated compacts into a smaller volume. Figure 4 illustrates miscellaneous PCB-contaminated waste before and after treatment, and illustrates the volume reduction potential.

After Treatment

Fig. 4. Before and After Photos of Treated PPE and Waste Material

Volume reduction of solids can also be accomplished in the SET™ process during pre-processing. Metal parts, plastics, personal protective equipment, and other solid materials can be shredded or cut prior to placement in the treatment cell. The net effect of this step is to reduce the volume considerably. The volume of these solid materials is further reduced by compaction after the treatment process as discussed above. While the volume of these materials is reduced, the weight of the treated material does increase by approximately 10-20 percent due to the sodium and acid added during the processing. The overall volume reduction that can be obtained with the SET™ process and pre-treatment techniques can exceed 60%.

The volume of aqueous liquids and oils is not reduced; however, material handling is improved. These liquids are usually converted to a solid or semi-solid salt mixture. This occurs because water reacts with solvated electrons to produce solid sodium hydroxide, which is subsequently converted to solid sodium sulfate during pH adjustment. This is especially useful for disposal of radioactive wastes because most radioactive waste sites cannot accept liquid waste.

Incineration of PCB wastes can produce dioxins as a secondary waste product. SET™ treatment of PCB waste does not produce any dioxins. In fact, SET™ is very effective at destroying dioxins. In many cases, dioxins accompany PCB contamination and the SET process destroys these dioxins along with the PCBs. Table VII list data for the SET™ treatment of dioxin containing waste.

Table VII. SET Renders Dioxins and Furans Non-detectable

Material/Matrix	Before-Treatment Levels (parts per billion)	After-Treatment Levels (parts per billion)
2378 TCDD Soil	46	Non-detectable
2378 TCDF Soil	39	Non-detectable
Dioxins (mix) Waste oil*	418.5	0.002
Furans Waste oil*	14.1	0.001

FINAL WASTE FORM PERFORMANCE AND CHARACTERISTICS

The final waste form is dependent on the form of the waste treated. For solids such as soils, the waste has the same general characteristics as the waste prior to treatment. Treated liquids usually have a changed characteristic. Oils may become more viscous. Aqueous liquids will become solids or semi-solids. Most organic liquids will become oily semi-solids. The pH of the waste will be adjusted to below 12.5. All waste will pass toxicity characteristic leaching procedure (TCLP) criteria. The photo below is the Pyranol residual material.

Approximately 50 grams of matrix; note dryness of material

Fig. 5. Post-treated Pyranol

Fig. 6. Complete SL-2 SET Plant, capable of treating 500 lbs/day of diverse waste types

SUMMARY OF CONCLUSIONS

SET™ operates as a non-thermal destruction process under low pressure. The process occurs in a closed system producing no hazardous off-gases and no regulated by-products such as dioxins or furans or their precursors. Advantages of SET™ include:

- Organic contaminants are destroyed, not just removed, diluted or concentrated.
- Operates as a closed system – produces no regulated secondary wastes.
- Holds an EPA permit for PCB destruction.
- Operates at ambient temperatures (70°F).
- Portable and sets up quickly in less than 4000 square feet of space.
- Scalable to accommodate any size waste stream.
- Requires minimal amounts of power, water and infrastructure.
- Applicable to heterogeneous waste streams in all phases.

The SET™ process is 99.9999% effective in destroying organic constituents of RCRA and TSCA waste, explosives and chemical-warfare agents; and has successfully destroyed many of the wastes listed in 40 Code of Federal Regulations (CFR) 261. The residual material meets land disposal restriction (LDR) and TSCA requirements for disposal.

In November 2007, Commodore completed a treatability study on Pyranol to determine the effectiveness of SET™ treatment on oil containing 600,000 PPM PCBs. Laboratory results proved destruction of PCBs to less than 1 PPM at low temperatures and pressures. SET™ is a proven, safe and cost-effective alternative to incineration for some of the most difficult waste treatment problems that exist today.