Increased Capabilities of Thermal Desorption - 9168

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ABSTRACT

Energy*Solutions* has been processing organically contaminated mixed waste through a vacuum assisted thermal desorption unit (TDU) at the Clive, Utah Treatment, Storage, and Disposal Facility (TSDF) since late 2003. Initial Demonstration Testing of the TDU was completed in September, 2004, and permitted operations for the processing of absorbed liquids, soil-like waste, and sludges have been ongoing since March, 2005. Over the past year, Energy*Solutions* has worked closely with regulators from the United States Environmental Protection Agency (EPA) and the state of Utah Division of Solid an Hazardous Waste (UDSHW) to develop permits and performance demonstration testing plans designed to increase the processing capabilities of the TDU. Increased processing capabilities include the free-release of condensate generated from radioactively contaminated waste, the processing of Polychlorinated Biphenyl (PCB) Large Capacitors, the processing of Mixed Waste with Resource Conservation and Recovery Act (RCRA) hazardous waste codes requiring the CMBST treatment technology, and the processing of elemental mercury and other volatile metals. Permit language has been written, processing parameters have been developed, and Demonstration Testing has been successfully conducted for all of these additional processing options. Based upon the parameters established during individual Demonstration Testing events, a majority of these capabilities are currently allowed on an interim basis. Final permitting is being completed to incorporate all of these processing capabilities into RCRA and Toxic Substance and Control Act (TSCA) permits for operation of the TDU at the Clive facility.

INTRODUCTION & HISTORY

The TDU system employed at the Clive facility is designed, constructed, and operated by TD*X Associates, LP (TD*X). The TD*X principals have experience with the thermal desorption process since the infancy of the technology back in the early 1990's. They are very knowledgeable in the theory and application of the technology and have been used constantly throughout the individual permitting processes described herein.

A history and description of the initial permitting process for the TDU at the Clive facility was provided in a previous Waste Management paper[1]. Permitting of the TDU requires waste to be categorized into specific waste families for testing and operational purposes. Waste families are defined as wastes with similar separation or regulatory characteristics. The addition of waste families requires a permitting process followed by a demonstration test for each waste family. The TDU was initially demonstrated in August and September, 2004, for the processing of two waste families: volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Polychlorinated Biphenyls (PCBs) were also demonstrated as a subset of the SVOC waste family. Based upon the results of this Demonstration Testing event, interim operations approval for the processing of VOCs and SVOCs was received from the UDSHW on March 8, 2005. Interim operations limits the total operating hours allowed during a week and requires a weekly status report be provided to the UDSHW. An attachment for thermal desorption processing has been added to Energy*Solutions*' State-issued Part B Permit which designates operating parameters of the TDU during this interim operating period.

A separate PCB demonstration approval dated April 19, 2004 was drafted by the EPA prior to the Demonstration Testing in 2004. This approval allowed the processing of PCBs through the TDU and also provided for the Demonstration Tests. Language within the draft allowed interim operations for PCB

processing through the TDU the moment a test report was submitted. The test report was submitted to the EPA on April 13, 2005. Interim operations from the EPA allowed any concentration of PCBs to be processed through the TDU. Final approval status was received from the EPA in a letter dated December 4, 2007. This approval was for mobile operations of the TDU. The approval limited the PCB concentration in the waste to 6,888 ppm PCBs. This limit was based upon the concentration of PCBs within the waste that was demonstrated in 2004.

Since operations were initially established, opportunities have arisen for additional waste processing through the TDU. This paper summarizes these additional opportunities and the permitting processes used to implement them.

TECHNOLOGY DESCRIPTION

The thermal desorption technology separates volatile contaminants from solid matrices by indirectly heating the contaminated material in a relatively inert atmosphere and condensing the resulting off-gas. Figure 1 provides a schematic block diagram of the thermal desorption process which consists of three major subsystems: a thermal separation system (dryer), an off-gas treatment train, and a condensate collection system.

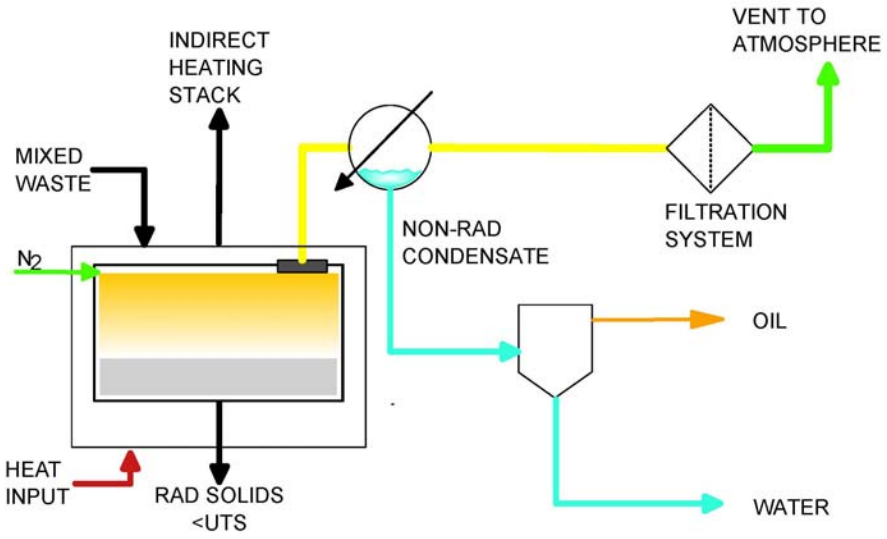

Figure 1. Thermal Desorption System Schematic Diagram

The dryer is a cylindrical vessel that is totally enclosed and indirectly heated by a separate propane fired furnace. Material within the dryer is never subject to an open flame. Further, the dryer is kept under vacuum and is purged with a nitrogen carrier gas such that the atmosphere within the dryer has a reduced oxygen concentration (generally less than 6% during operation).

Waste (feed material) is introduced into the dryer through a feed hopper. The waste in the dryer is brought up to a predetermined temperature and then discharged as processed material. During heating, lower boiling contaminants within the waste are volatilized and the off-gas is conveyed through a system of condensers and filters to remove the volatile contaminants from the off-gas prior to emission to the

atmosphere. The condensate is collected for future management; typically incineration at a RCRA permitted facility. The processed material is a dry solid material that is below EPA treatment standards for volatile contaminants.

The TDU employed at the Clive facility is the most advanced thermal desorption system constructed by TD*X. It has been specifically designed to meet the rigorous requirements necessary to process radioactively contaminated hazardous waste (mixed waste). To distinguish this unit from other units constructed by TD*X, it has been designated within the EPA approval as the High Performance Thermal Desorption Unit (HP-TDU). Many of the additional capabilities described in this paper would not be possible with a less-robust system.

ADDITIONAL CAPABILITIES

Condensate Release

Proper operation of the TDU creates a concentrated liquid condensate that requires appropriate treatment. Energy*Solutions* has looked into several treatment possibilities for the condensate generated during TDU processing. The only viable option currently available is combustion. Furthermore, the condensate generally has an excellent heating value and is perfectly suited for combustion. However, very few options exist for the combustion of radioactively contaminated waste, particularly waste that is contaminated with PCBs.

In addition to separating volatile materials from the solid feed, the TDU has been designed to separate radioactively contaminated particles from the condensate. In general, the radioactivity remains within the solid processed material that remains in the dryer and is not volatilized with the condensate. This design principle could be used to its fullest advantage if criteria were established and met that allowed the condensate to be considered "not radioactively contaminated" (free-released from the radiological standards). Several commercial hazardous waste incinerators are operating across the United States that could accept non-radioactive condensate for treatment by combustion.

The issue at hand is the need for a free-release mechanism for liquid condensate. The Nuclear Regulatory Commission (NRC) has not provided guidance or a position on this activity. Many regulatory bodies will not touch this subject without previous NRC guidance. However, the TD*X principals were familiar with state regulators in South Carolina. They approached these regulators to ascertain whether the idea of releasing condensate from radioactivity was a viable alternative. As justification for this concept, the South Carolina regulators were provided detailed confidential information regarding operation of the TDU operated at the Clive Facility. Based on a thorough review of this information, TD*X received approval to begin the permitting process on a facility that would enable the free-release of condensate that was managed through that facility.

TD*X established the TD*X Technical Center, a transfer facility in Marietta, South Carolina. This transfer facility was issued a Radioactive Material License from the state of South Carolina on February 23, 2007. Under its license, the facility is permitted to receive condensate generated from the TDU at Clive and complete a radioactive free release of the waste if it meets the following criteria:

- The condensate is exempt from marking and labeling as radioactive material in accordance with Department of Transportation (DOT) regulations[2].
- The condensate is exempt from labeling as radioactive material in accordance with NRC regulations[3].
- A sample of the condensate has a radioactivity measurement in counts per minute less than three times background at the surface of the sample container.

These criteria are demonstrated by collecting a representative sample of the condensate shipment, including aliquots from all containers in the shipment, and analyzing for radiological parameters. Once these samples are collected at the Clive facility, all of the condensate containers sampled are custody sealed and certified. No additional condensate may be added to these containers after this action.

An initial shipment of condensate was sampled, analyzed, and shipped to the TD*X Technical Center in South Carolina on April 19, 2007. This condensate was free-released and incinerated at the Veolia Environmental Services hazardous waste incinerator located in Port Arthur, Texas on August 5, 2007. Note that the incinerator also performs a radioactivity check on all waste entering the facility prior to incineration. No issues were noted and the process operated smoothly from start to finish. Additional shipments have been made since this time and the free-release mechanism is now a viable option for condensate generated through the TDU at Clive.

PCB Large Capacitors

The PCB regulations[4] require disposal of PCB Large Capacitors within an approved incinerator; land disposal of PCB Large Capacitors is not permitted. This regulatory requirement was confirmed by Dr. John Smith in a phone consultation in 2003. For radioactively contaminated PCB Large Capacitors, incineration options are limited to one facility, the Toxic Substance and Control Act Incinerator (TSCAI) owned by the Department of Energy (DOE) in Oak Ridge, Tennessee.

The urgency of the need for an alternative arose when a shipment of radioactively contaminated PCB Large Capacitors from the DOE's Rocky Flats Environmental Technology Site (RFETS) was prepared for disposal in the TSCAI, but could not be accepted at the incinerator due to high lead concentration (up to 6%) in the waste. An alternative was required for this orphan waste.

The TDU EPA approval is based upon the alternatives to incineration methodology in 40 CFR 761.60(e). In this methodology, a facility will not be allowed to process PCBs unless it is demonstrated to achieve a level of performance equivalent to a TSCA approved incinerator. This demonstration was satisfactorily completed in the 2004 tests for wastes up to 6,888 ppm PCBs. With this as a basis, the EPA was informally approached about the possibility of processing PCB Large Capacitors through the TDU, incinerating the condensate, and allowing the solid processed material to be disposed on-site in the Mixed Waste Landfill Cell. EPA personnel agreed that this alternative would be within the purview of the TDU approval; however, an additional demonstration test would be necessary to ensure the higher PCB concentrations could be successfully processed through the TDU. Additionally, the State-issued Part B Permit described specific waste matrices (soil-like material and sludges) that were previously demonstrated. Debris-type material, such as shredded capacitors, would need an additional demonstration to ensure processing of this matrix could be successfully conducted with the TDU.

With consent from both the EPA and UDSHW, a Demonstration Test Plan was drafted and sent out for approval. The plan described the daily details of the Demonstration Test and provided information on the feed material (RFETS PCB Large Capacitors) and the key personnel and contractors that would be utilized during the test. The plan was approved and testing commenced on April 1, 2008 with both EPA headquarters and UDSHW regulators present.

The Demonstration Test consisted of three process cycles (batches) completed over three days of operation. In preparation for incineration at the TSCAI, the PCB Large Capacitors had been shredded by a third party processor prior to receipt at Energy*Solutions*. Energy*Solutions* completed additional shredding to meet the four-inch size requirement of the TDU and re-packaged the waste into appropriate containers for TDU processing. Each process cycle of the Demonstration Test consisted of a single drum of pre-processed PCB Large Capacitors. A composite sample of the feed waste was collected from each process cycle as the waste was fed into the TDU. The condensate and the processed material generated

from each process cycle were also sampled. These three samples were all analyzed for total PCBs (as found in the seven most prevalent Aroclors).

Emission testing was also conducted by taking a slip stream from a four-inch manifold specifically designed to collect emission samples using EPA stack testing methods. The manifold was located outside the controlled area after the condensers and filters, but before the final emission point of the TDU. The off-gas was sampled and analyzed for total PCBs and for polychlorinated dibenzo-p-dioxins and furans (PCDD/PCDF).

Table I. PCB Large Capacitors Demonstration Test Summary

Process Cycle	Feed Weight (lbs)	Process Cycle Time (min)	PCB Concentrations			
			Feed (mg/kg)	Processed Material (mg/kg)	Condensate (mg/kg)	Off-Gas (μg/hr)
1	1,168	210	148,300	< 0.003	38,080	2.26
2	976	171	165,000	0.0333	120,000	14.90
3	1,122	168	174,900	< 0.003	109,000	12.90

The feed samples detected PCB concentrations from 148,300 to 174,900 ppm. The PCB concentration was non-detectable in the processed material of the first and third process cycles and detectable at 0.0333 mg/kg in the second process cycle. This is well below the EPA required limit for the TDU of 2 mg/kg. Emission testing also detected small amounts of PCBs. A summary of the Demonstration Test is provided in Table I. In addition to these PCB results, the PCDD/PCDF total toxicity equivalent emission was only 0.0055 mg/dscm, orders of magnitude below the TDU EPA approval limit of 1.0 mg/dscm.

The collected data was used to calculate the TDU removal efficiency (RE) and the potential risks to the public from the emission. The TDU RE is defined as the amount of contaminant removed from the feed material prior to reaching the off-gas. It is calculated by dividing the off-gas rate by the feed rate. For this Demonstration Test, the RE ranged from 99.9999998 to 99.99999997%. A risk assessment was utilized using the EPA's SCREEN3 modeling software and the concentrations present within the off-gas. The conservative maximum cancer risk to a child residing at the point of maximum concentration ranged from 6×10^{-11} to 1×10^{-10}. The conservative maximum non-cancer risk (Hazard Quotient; HQ) to a child residing at the point of maximum concentration ranged from 0.02 to 0.05. The action levels for these risks are a cancer risk of 1×10^{-6} and an HQ of 1.

Detailed reports of the Demonstration Test were provided to the EPA and the UDSHW. Based upon these reports, Energy*Solutions* and TD*X were given approval to complete the waste population of capacitors from RFETS. The remaining capacitors were processed on June 18-19, 2008 and the entire waste population was disposed in the on-site Mixed Waste Landfill Cell on September 23, 2008. Final permit language for future processing is currently being negotiated with the EPA.

CMBST-Coded Wastes

The RCRA regulations[5] contain 139 hazardous waste codes that require the CMBST treatment technology in order to meet Land Disposal Restrictions (LDR). No other alternatives are provided for these 139 hazardous waste codes. By definition, the LDR must be met before a hazardous waste may be land disposed. The CMBST treatment technology is defined in 40 CFR 268.42 as "High temperature organic destruction technologies, such as combustion in incinerators, boilers, or industrial furnaces operated in accordance with the applicable requirements of 40 CFR part 264, subpart O, or 40 CFR part 265, subpart O, or 40 CFR part 266, subpart H, and in other units operated in accordance with applicable

technical requirements; and certain non-combustive technologies, such as the Catalytic Extraction Process."

An alternative to this treatment technology was required for a population of approximately 50 cubic yards (~ 45,000 lbs) of legacy waste sludge from the DOE Oak Ridge Facility. The waste included many hazardous waste codes that required the CMBST treatment technology as well as other organic and inorganic hazardous waste codes. The only outlet for combustion of this waste was the TSCAI; however the high inorganic (metal) content within the waste precluded the use of that facility. Once again, an alternative was required for this orphan waste.

Through demonstration testing and normal operations, the TDU has proven to treat organics within the solid processed material to levels commensurate with an incinerator. Energy*Solutions* proposed to use this information to justify the processing of wastes with CMBST-codes through the TDU and disposing of the processed material as LDR compliant within the on-site Mixed Waste Landfill Cell. On March 31, 2006, Energy*Solutions* took this information and went to the UDSHW with a proposal for a local, site-specific treatment variance to allow this activity, in accordance with 40 CFR 268.40(h). Discussions concluded that this action was not in the purview of the state and would need to be managed through the EPA. The next step sent Energy*Solutions* to EPA Region 8 for guidance on a path forward. The local region provided guidance that the request could be made as either a Determination of Equivalent Treatment (DET) or a variance request from the rules. Both of these avenues would require working with EPA headquarters in Washington, D.C.

The EPA region 8 representatives put Energy*Solutions* in touch with the appropriate EPA headquarters staff involved in this type of process. Discussions with the EPA headquarters representatives ruled out a DET as this rulemaking is frowned upon and is no longer given except in dire circumstances. It was suggested that a variance request be prepared and submitted for EPA headquarters consideration for rulemaking. In support of this action, the EPA sent Energy*Solutions* a variance assistance document, which provided a reference and framework for the variance request process. This document was very helpful in creating an official variance request submission.

Using the information provided by the EPA, a petition for a treatment variance was submitted to the EPA in a letter dated August 28, 2006. A summary of the variance request was presented in a paper by Otis Willoughby at the WM2008 Conference[6]. The variance was requested for all discarded commercial chemical products (P- and U- hazardous waste codes) that require the CMBST treatment technology (with no alternatives) in order to meet LDR. The overlying justification for this action was that the TDU is designed to separate feed waste into a solid processed material (that contains very little volatile contaminants) and a concentrated condensate that would be sent off-site to a permitted incinerator. The assumption is that the CMBST-coded contaminants would be volatile and would be concentrated in the condensate while the processed material would no longer contain the CMBST-coded contaminants and could be disposed in the onsite Mixed Waste Landfill Cell.

Justifications for this variance included:

- Limited options exist for disposal of this waste and, with the high heavy metal concentrations present, would not be feasible (very slow incinerator feed rate), if possible at all;
- Data from the previous three years of operation demonstrated that the TDU had consistently shown successful separation of volatile constituents with similar boiling points to the CMBST-coded contaminants;
- Analysis of the TDU processed material will demonstrate that none of the analyzable CMBST-coded constituents will be present;
- The CMBST-coded contaminants will be concentrated in the condensate which will be sent to a permitted facility for treatment using the CMBST technology. Furthermore, the condensate is

much more amenable to the combustion process than the original waste (higher BTU, liquid composition, very low metals) and a great deal less ash is generated from this combustion;

- The condensate has a minimal amount of radioactivity within it; therefore, the TDU process minimizes the amount of radioactively contaminated material combusted and potentially released to the environment; and
- Metal contaminants remaining in the solid processed material will be stabilized on-site, using permitted techniques and approved stabilization formulas, to concentrations below LDR prior to disposal.

One area of the regulations that had to be overcome during this action was the fact that many of the CMBST-coded wastes cannot be analyzed using typical EPA-approved analytical methods. To combat this issue, Energy*Solutions* proposed to conduct another Demonstration Test with waste containing CMBST-coded contaminants spiked with surrogates representing boiling point temperature ranges of the CMBST-coded contaminants. Boiling point temperature ranges were chosen to categorize the CMBST-coded wastes waste family since boiling point is the primary chemical characteristic for successful separation through the TDU.

During subsequent discussions and rulemaking development, EPA considered UDSHW the primary contact for this issue. All communications were made through this avenue. Direct communications between the EPA and Energy*Solutions* was kept to a minimum. Over the next ten months, email and verbal discussions continued between the UDSHW and the EPA. Energy*Solutions* was informed of these discussions through the UDSHW and was able to continually supply information to keep the process moving along. Information provided for the EPA docket included:

- CMBST-coded contaminants boiling point data;
- Radiochemical data from previously generated TDU condensate;
- Previous Demonstration Test data of the feed, processed material, and condensate;
- Various processed material verification analytical data – from normal TDU operations;
- Drawings of the Clive Facility and the TDU set-up; and
- Supplementary Energy*Solutions* procedures (data review, TDU operations, etc.).

In July, 2007, the EPA provided a draft template for the proposed rulemaking and asked Energy*Solutions* (through the UDSHW) to fill in the required information. This template only provided guidance on what should be in different sections of the rulemaking and contained very little substance about this specific rulemaking. Energy*Solutions* and UDSHW personnel worked together to complete the template within several weeks of receipt. The completed document was submitted back the EPA. Very little action was noticed for several months after this document was submitted.

On January 15, 2008, Energy*Solutions* initiated a conference call with EPA representatives and the UDSHW. The purpose of this call was to instill the urgency for completion of the request as a TDU campaign was beginning in February and may be operational for only 60 to 90 days. If the waste was not able to be processed in that time frame, it may never get processed and could remain an orphan waste. The EPA responded favorably to this plea and promised to push the rulemaking through to completion. It was mentioned that there review was almost complete and that they believed the rulemaking was so straightforward and the arguments so substantive that they could issue a Direct Final Rule in the Federal Register (FR).

A Direct Final Rule was published in the Federal Register on March 6, 2008[7]. The Direct Final Rule stipulated that the rule would be effective May 5, 2008 without further notice unless adverse comments were received before April 7, 2008. EPA policy states that any adverse comments, whether substantial or

not, could override the Direct Final Rule and require a response prior to final rulemaking. Four comments were received from the Direct Final Rule: two were related to another issue, one was in favor of the rulemaking, and one questioned whether radioactive waste should be treated in Utah at all. Although this comment had no basis, EPA policy required that the Direct Final Rule be withdrawn and the comments addressed in a final rule notice. Based on this comment, the Direct Final Rule was withdrawn on April 30, 2008[8]. However, EPA personnel were true to their promise to keep the processing moving and a final rule was written addressing all of the comments and was published in the Federal Register on May 14, 2008[9]. This notice stated that the final rule would be effective on June 13, 2008.

Part of the rulemaking required that a Demonstration Test be conducted for the TDU. The EPA gave the UDSHW complete authority for overseeing and reviewing data from this test. Through the UDSHW, this also required that the permit modification process be conducted to add a new attachment to the permit. With approval from the regulatory bodies, this action was performed in conjunction with the EPA rule making process. A Class 2 Modification to the Clive facility State-issued Part B Permit was submitted to the UDSHW on January 25, 2008. This Permit Modification added the "Thermal Desorption CMBST-Coded Waste Pre-Demonstration Plan" attachment to the permit.

The new attachment defined the CMBST-coded wastes waste family and provided the details of the Demonstration Test required to be conducted. The objective of the Demonstration Test presented in this attachment was to determine if the TDU provides adequate separation of wastes containing CMBST-codes and ensure that emissions are not harmful to the public or the environment. To this end, the attachment required a demonstration test consisting of three TDU process cycles fed with wastes containing CMBST-codes. The attachment defined Principal Organic Hazardous Constituents (POHCs) to be used as surrogates to represent subcategories of the CMBST-coded wastes waste family. The subcategories were created based upon separation characteristics of the waste, with boiling point (BP) being the primary chemical characteristic for separation through the TDU. The CMBST-coded wastes waste family has boiling points ranging from -2.4 ˚F for formaldehyde (U122) to 993.2 ˚F for mitomycin C (U010). Table 2 lists the three CMBST-coded wastes subcategories developed for this waste family and the POHCs associated with each subcategory. The POHCs were chosen based upon their availability (since they needed to be spiked into the feed) and their applicability to the boiling point range of the subcategory. A pure product POHC could not be found for the higher boiling point category. Instead, a coal tar was used that contained a mixture of polycyclic aromatic hydrocarbons (PAH) at relatively high concentrations. Rather than examining all of these PAHs separately as surrogates, fluoranthene was chosen as the surrogate due to its high boiling point and high concentration in the coal tar.

Table 2. CMBST-Coded Waste Surrogates

CMBST Waste Family Subcategory	POHC(s)
BP < 400 ˚F	Trichloroethene, o-Cresol
400 ˚F < BP < 600 ˚F	Dibenzofuran
BP > 600 ˚F	Fluoranthene (in coal tar)

The attachment also described sampling and analysis methodology that was to be utilized during the Demonstration Test. This included samples of the feed, processed material, condensate, and off-gas. Acceptance criteria defining success of the Demonstration Test were also included in the attachment.

The Class 2 Modification required a 60-day public comment period before implementation. The comment period concluded with no comments received. The UDSHW approved the modification on April 23, 2008. The new Permit Attachment created by the modification included a requirement that a Demonstration Testing Plan be submitted to the UDSHW at least one week prior to the beginning of the

Demonstration Test. This Demonstration Testing Plan is to provide the day-by-day details of the test, describe the feed and spiking compounds, define key personnel, and provide a sampling matrix for all samples that will be taken during the test.

The Demonstration Test was conducted over three days from April 29 through May 1, 2008 with UDSHW regulators present throughout. During the test, each process cycle had samples collected for VOCs and SVOCs from the feed, processed material, and condensate. In addition, the tar spiked into each process cycle feed was also sampled and analyzed for VOCs and SVOCs. The off-gas stream was also sampled through the manifold outside the restricted area for VOCs, SVOCs, and hydrochloric acid (HCl; an indicator of combustion). The data collected was used to calculate REs of the POHCs and primary known waste contaminants (those waste contaminants that have an individual contribution of more than 1% to the total organic composition) and to perform conservative risk assessments for a child located at the point of maximum concentration.

Calculated REs for the POHCs of each process cycle are described in Table 3. All REs easily met the acceptance criterion of 99.99% (four-nines). Furthermore, all primary known waste contaminants had REs of 99.99% or greater. Child cancer risks ranged from 6×10^{-11} to 8×10^{-12}. Child hazard quotients ranged from 0.01 to 0.003. Total mass balances over each process cycle were also calculated, demonstrating that separation was the primary treatment mechanism throughout the test. Furthermore, no HCl was detected in the off gas, demonstrating that combustion was not occurring in the TDU. All of this data was compiled and discussed in a Post-CMBST Report submitted to the UDSHW on July 15, 2008.

With this report submission, Energy*Solutions* requested that interim operations be granted in order to process the remainder of the CMBST-coded waste on site. After reviewing the data for completeness and discussing issues with Energy*Solutions*, the UDSHW granted interim operations in a letter dated August 20, 2008. Upon receiving this authorization, the remainder of the CMBST-coded waste was processed, verified LDR compliant, and disposed in the Mixed Waste Landfill Cell prior to the end of the fiscal year, September 30, 2008.

Table 3. CMBST-Coded Wastes Demonstration Test RE Evaluation

Process Cycle Date	POHC	Feed Conc. (mg/kg)	Off-Gas Rate (µg/hr)	RE (%)
April 1, 2008	trichloroethene	6,233	62.10	99.999990
	o-cresol	5,828	20.5	99.999996
	dibenzofuran	167	< 18.6	99.99989
	fluoranthene	113	5.0	99.99995
April 2, 2008	trichloroethene	5,940	62.7	99.999994
	o-cresol	4,914	< 51.7	99.999994
	dibenzofuran	169	< 51.7	99.9998
	fluoranthene	137	3.9	99.99998
April 3, 2008	trichloroethene	9,068	32.5	99.999998
	o-cresol	4,782	4.3	99.9999995
	dibenzofuran	180	< 39.2	99.99990
	fluoranthene	91	3.7	99.99998

Mercury Processing

The separation characteristics and emission control of mercury was distinctive enough to be considered a separate waste family from other volatile materials. Examining the market, Energy*Solutions* did not feel compelled to include mercury in the initial permitting action. However, it became apparent that something needed to be done because the permit, as written, did not allow any waste that was hazardous for mercury to be processed through the TDU. This became an issue when waste with mercury concentrations slightly above treatment standards was received for TDU processing. In order to process this waste through the TDU, it had to first be stabilized to concentrations below the treatment standards described in 40 CFR 268. This generally meant the addition of large quantities of sulfur or sulfurous compounds. Sulfur has a boiling point of approximately 833 ˚F and volatilizes during TDU operations, plugging the condensers and piping. Cleaning out this equipment realized the potential for emitting large quantities of hydrogen sulfide which caused concern for personnel working in this area. To avoid these health and safety as well as operational issues, processing of mercury needed to be allowed by the Permit.

Additionally, the TDU meets the definition described in 40 CFR 268 for the RMERC treatment technology. RMERC is described as "retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery." The addition of this treatment technology would provide more flexibility for processing waste at the Clive facility.

Discussions were made with UDSHW personnel prior to initiating any permitting action. These discussions concluded that a permit modification was required for other metals, in addition to mercury. Based upon the potential volatility of other metals, and to ensure the protection of public health and the environment, the UDSHW concluded that a permit was necessary for the broader category of volatile metals. This became a waste family unto itself, borrowing the definitions provided in the incinerator MACT standards[10]. These standards define three categories of "volatile" metals: high volatile metals (mercury), semivolatile metals (cadmium and lead), and low volatile metals (arsenic, beryllium, and chromium).

A Class 2 Permit Modification was submitted to the UDSHW in a letter dated February 21, 2008. The Permit Modification introduced another new attachment to the State-issued Part B Permit entitled "Thermal Desorption Volatile Metals Pre-Demonstration Plan." This new attachment defined the volatile metals waste family and provided the details of another Demonstration Test that was required to be conducted.

In order to challenge the system, and provide a worst-case demonstration, the new attachment called for spiking of the feed waste with high concentrations of volatile metals or volatile metal compounds. These spikes were the volatile metals counterpart of POHCs and were dubbed Representative Volatile Metals (RVMs). RVMs included elemental mercury to represent the high volatility metals category, lead acetate to represent the semivolatile metals category, and arsenic trioxide to represent the low volatile metals category. Lead acetate was chosen as an RVM because it decomposes at a relatively low temperature (~212 ˚F) and is considered a more volatile form of lead than is normally encountered. Similarly, arsenic trioxide is a more volatile form of arsenic with a boiling point around 869 ˚F.

The new attachment described acceptance criteria for a successful Demonstration Test from the perspective of the separation of mercury (processed material had to be less than 260 mg/kg after processing) and protection of public health and the environment. These acceptance criteria include:

- The processed material mercury content must be less than 260 mg/kg;
- RVM REs must be greater than 99.99%;
- MACT standards for an existing incinerator have to be met; and
- A risk assessment must show a cancer risk less than 10^{-6} and an HQ less than one for a child residing at the point of maximum concentration.

No comments were received during the public comment period for this Permit Modification; however, internal discussions between Energy*Solutions* and the UDSHW continued and the document was refined over the next several months. In early August, the UDSHW was informed that an accelerated schedule was necessary due to time constraints with the TDU contract at Clive. The UDSHW worked with Energy*Solutions* and verbally approved the Permit Modification on August 19, 2008; with a written approval following on August 20, 2008. The verbal approval was necessary so that Energy*Solutions* could submit the required Demonstration Testing Plan seven days before the initiation of the Demonstration Test which began on August 26, 2008.

Three days of testing commenced on three spiked process cycles August 26-28, 2008. Table 4 lists the RVM spike details and the resulting REs. Metal concentrations were calculated using the stoichiometric weight of each metal within the compound. In addition to these metals, trichloroethene was also spiked into the feed at concentrations between 10,000 and 18,000 mg/kg. This spike was included to provide a greater challenge to the TDU since chlorinated compounds tend to increase the volatility of metal contaminants.

Table 4. Volatile Metals Demonstration Test Summary

Process Cycle Date	RVM	Weight of Spike (lbs)	Weight of Metal (lbs)	Metal Feed Conc. (mg/kg)	Metal Emission Rate (µg/hr)	RE (%)
August 26, 2008	Arsenic Trioxide	20.03	15.09	14,758	< 2.8	99.9999998
	Lead Acetate	35.21	22.43	26,199	< 9.8	99.9999996
	Mercury	15.36	15.36	14,988	50.00	99.999996
August 27, 2008	Arsenic Trioxide	24.99	28.09	13,382	10.1	99.9999994
	Lead Acetate	44.11	18.83	22,577	< 8.8	99.9999997
	Mercury	17.47	17.47	12,376	37.0	99.999998
August 28, 2008	Arsenic Trioxide	12.57	9.47	9,521	278.0	99.9998
	Lead Acetate	31.45	20.03	23,132	< 12.6	99.9999995
	Mercury	12.68	12.68	12,747	106.0	99.999993

These Demonstration Test results showed that contaminant REs easily met the acceptance criterion of 99.99% even using the conservative method detection limit values for some of the metals. Furthermore, additional REs were calculated for all metals found in the waste feed and all met the criterion of 99.99%. The MACT standard results are described in Table 5. All of these results were within the acceptance criteria (MACT Standards). The mercury concentration in the processed material ranged from 0.6 to 1.2 mg/kg with nothing detected in the TCLP analysis. The child cancer risks ranged from 2×10^{-9} to 8×10^{-9} with an HQ from 0.01 to 0.03. Therefore, all acceptance criteria were met and the Demonstration Test was successful. A Post-Volatile Metals Demonstration Testing Report was submitted to the UDSHW on October 21, 2008.

Table 5. Volatile Metals MACT Standard Results

MACT Metals	MACT Standard (µg/dscm)	8/26/08 Result (µg/dscm)	8/27/08 Result (µg/dscm)	8/28/08 Result (µg/dscm)
Mercury	130	2.63	0.13	0.22
Cadmium + Lead	240	0.74	4.57	1.22
Arsenic + Beryllium + Chromium	97	26.67	6.40	30.69

FUTURE WORK

Currently, the TDU is operating under interim operating conditions for VOCs, SVOCs, and CMBST-coded wastes. An interim operations period for volatile metals has not been received as of this date. The next step in the permitting process is to compile the information from all of the Demonstration Tests and modify the TDU operations section of the State-issued Part B Permit to include all of the successfully demonstrated capabilities. This permitting process will include a definition of all waste families and waste matrices which may be processed through the TDU. The permitting process may also define a feed rate limit for metals concentrations; however, based on the results of the Demonstration Test and the fact that waste streams destined for TDU processing generally have low concentrations of metals, it has been suggested that a feed rate limitation is not necessary. All of this information will be compiled into a Class 2 or Class 3 Permit Modification request in the near future.

The EPA TSCA Permit is currently being updated to allow feeding waste with the additional PCB concentrations demonstrated in the PCB Large Capacitors Demonstration Test. Additional waste received since this test has determined that an even larger feed concentration of PCBs may be required in the future. This limit may need to be raised to a pure PCB liquid waste stream that has been solidified. Discussions are ongoing about potentially allowing dilution prior to TDU processing or slower feed rate processing in order to process the waste under the demonstrated parameters. If necessary, another Demonstration Test may be forthcoming at higher feed rates. Past performance of the TDU provides confidence that acceptance criteria will be met at any concentration of PCBs.

Additional permitting action with EPA Region 8 is currently underway to change the approval from a mobile permit to permanent operations at the Clive facility. This action is expected to be completed within the next six months.

CONCLUSION

Energy*Solutions* has successfully demonstrated the effectiveness of the TDU located at the Clive facility to separate volatile contaminants from feed waste streams. Lessons have been learned that reasonable out-of-the box thinking is accepted by regulatory bodies as long as the theory is based in fact and can be proven. Open and honest communication with regulators leads to action and helpfulness on their part. However, patience is needed as the course taken to complete the permitting actions required to process different wastes will take time and may take different twists and turns before final approval.

REFERENCES

1. T. Orton, “RCRA Permitting of a Vacuum Thermal Desorption System”, Waste Management 2005, February 27-March 3, 2005, Tucson, AZ.

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3. Code of Federal Regulations (CFR), Title 10, Energy, Part 20, Standards for Protection against Radiation

4. Code of Federal Regulations (CFR), Title 40, Protection of Environment, Part 761, Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions

5. Code of Federal Regulations (CFR), Title 40, Protection of Environment, Part 268, Land Disposal Restrictions

6. O. Willoughby, M. Christensen, and T. Orton, “Development of a US EPA Variance for Mixed Wastes Designated with a Combustion Treatment Code Destined for the Energy*Solutions* Mixed Waste Facility,” Waste Management 2008, February 24-28, 2008, Phoenix, AZ.

7. 73 FR 12017 (March 6, 2008)

8. 73 FR 23361 (April 30, 2008)

9. 73 FR 27761 (May 14, 2008)

10. Code of Federal Regulations (CFR), Title 40, Subpart EEE, National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors