

THERMAL DESORPTION-SUPERCRITICAL WATER OXIDATION OF ORGANICS IN TRANSURANIC MIXED WASTES

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INTRODUCTION

The United States Department of Energy's (DOE's) Savannah River Site (SRS), near Aiken, South Carolina, stores Plutonium-238 contaminated heterogeneous waste that requires treatment to remove organic materials. This waste may not be shippable to the Waste Isolation Pilot Plant (WIPP) in TRUPACT-II containers due to excessive generation of hydrogen gas as a result of radiolysis of organic constituents in the waste matrix. General Atomics (GA) proposes to demonstrate a two-step alternative to incineration for the destruction of the organic constituents in the SRS wastes. GA's two-step process is a combination of two well-known and effective treatment processes, thermal desorption (TD) and supercritical water oxidation (SCWO), to achieve a new level of simplicity and treatment effectiveness in compliance with all regulatory and environmental requirements.

GA's new process combines the best attributes of each technology to achieve enhancements not possible with either technology alone, or with other potentially competitive technologies. TD is well established as a treatment process for removal of organics from difficult solid matrices such as soils and mixed wastes. Steam and heat are used to volatilize, gasify, and transport organics from the inorganic residue for subsequent treatment. SCWO is a well-developed nonincineration process for destruction of organics in pumpable forms such as liquids and slurries of finely divided particles. SCWO oxidizes organics in an aqueous medium at elevated temperatures and pressures in a manner that achieves excellent destruction efficiencies and compliance with all environmental requirements without the need for complex pollution-abatement equipment. GA combines these processes to achieve complete removal and destruction of organics from solid matrices with minimal pretreatment and posttreatment requirements.

DOE has awarded a contract to GA to perform Phase I Cold Demonstration Tests with existing GA-owned equipment using surrogate wastes at GA’s facilities in San Diego, California, to demonstrate that TD-SCWO can meet or exceed all of the specified process requirements. Following successful proof-of-principle demonstration of TD-SCWO for SRS surrogate wastes, GA plans to perform follow-on tests with surrogate and actual SRS wastes at a suitable DOE facility, and to define requirements for a production system to process SRS wastes.

OBJECTIVES

The SRS stores high-activity plutonium-238-contaminated transuranic waste. This waste may not be shippable to the WIPP in TRUPACT-II containers due to excessive generation of hydrogen gas as a result of radiolysis of organic constituents in the waste matrix. The target SRS waste is, for the most part, miscellaneous job-control waste (e.g., protective clothing, cloth, paper, rubber, swipes, rags, booties, glassware, small metal objects, pieces of equipment, wood, plastic, etc.) from on-site TRU-generating facilities. This waste is contaminated with TRU isotopes in quantities suspected to be >100 nCi/g and <.5 Ci/package. Further, this waste contains RCRA hazardous materials such as lead, mercury, cadmium, and various solvents. Treatment of this waste to either destroy the organics eliminating the source of hydrogen, or decontamination to remove a significant portion of the plutonium-238 contamination, would allow the waste to meet the TRUPACT-II hydrogen-concentration limit and the WIPP waste acceptance criteria (WAC), in accordance with the requirements in Table 1 and all environmental regulations.

TABLE 1 WIPP AND TRUPACT-II WASTE ACCEPTANCE CRITERIA FOR SRS MTRU WASTE PROCESSING REQUIREMENTS		
Waste Type	Waste Acceptance Criteria	TD-SCWO Compliance with Criteria*
Free liquids	Less than 1 volume % of external container Less than 1 in. in bottom of internal containers	High temperature in TD (>1000°F) will ensure that no free liquid remains
Pyrophoric materials	<1% radionuclide pyrophorics No nonradioactive pyrophorics	High temperature in TD will ensure that no pyrophoric materials remain
Sealed containers	No sealed containers greater than 4 liters	High pressure and temperature in TD will ensure that all sealed containers (nonpressure vessels) are opened due to pressure or thermal expansion of contents.
Hazardous waste	Limited to RCRA hazardous waste codes that ensure no ignitable, corrosive, or reactive characteristics	High temperature in TD will ensure that no ignitable, corrosive, or reactive constituents remain.
Explosives, corrosives, and compressed gases	No explosives, corrosives, or compressed gases	High temperature in TD will ensure that no explosives remain.
Headspace gas VOC concentrations	Every container will be headspace gas sampled	High temperature in TD will ensure that no VOCs remain.
PcB concentration	<50 ppm	High temperature in TD will ensure that no PCBs remain.

TABLE 1 WIPP AND TRUPACT-II WASTE ACCEPTANCE CRITERIA FOR SRS MTRU WASTE PROCESSING REQUIREMENTS (CONT'D)		
Waste Type	Waste Acceptance Criteria	TD-SCWO Compliance with Criteria*
Test category waste	Steady-state hydrogen gas generation rate is less than or equal to the rate specified in the TRUPACT-II Safety Analysis	High temperature in TD will ensure that residual hydrogen content is less than 0.5 wt %
Flammable VOCs	<500 ppm total in the headspace of any payload container	High temperature in TD will ensure that no flammable VOCs remain.

*Materials removed from the containers by TD are subsequently completely destroyed by SCWO.

Under the Program Research and Development Announcement (PRDA) No. DE-RA26-01NT40981 for “Decontamination/Destruction Technology Demonstration for Organics in Transuranic Waste,” DOE is seeking to demonstrate technologies for the decontamination and/or destruction of the organics in mixed transuranic (MTRU), heterogeneous waste. Incineration technologies are specifically excluded. The work will be performed in phases as follows:

- Phase I — Proof of Principle Cold Demonstration (all technologies)
- Phase II — Proof of Principle Actual Waste Demonstration (decontamination technologies)
- Phase III — 1/5th or Larger Scale Cold Demonstration (future option)
- Phase IV — 1/5th or Larger Quantification and Actual Waste Treatment (future option)

Following successful completion of Phase I, GA plans to perform Phase III and Phase IV testing at a suitable DOE site, and then to design, build, and operate a full-scale system to treat actual wastes at the SRS site.

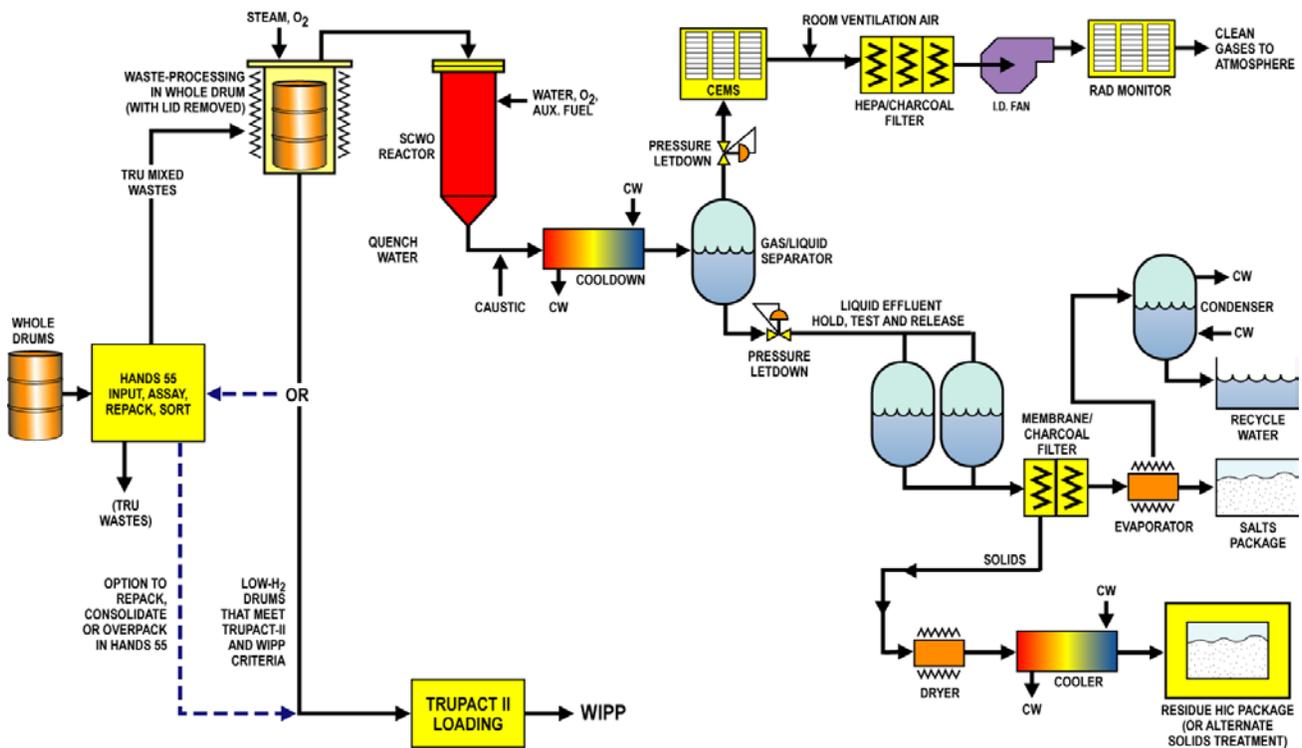
TECHNICAL APPROACH

The integrated TD-SCWO results in performance enhancements not possible with either process individually. Traditionally, TD generally requires an afterburner and a complex pollution-abatement system (PAS) to destroy the desorbed organics, thus violating the non-incineration objective and compromising permitting and public acceptance. Additionally, the afterburner increases the likelihood of dioxin formation. For the SRS application, the spread of Pu-238 contamination throughout the afterburner and PAS further compromises traditional TD technology. Traditionally, SCWO feed materials must be liquids or finely ground solids that can be slurried and pumped to high pressure. With TD-SCWO, however, TD desorbs organics from any form of solids and delivers the gas-phase organics to SCWO, thus resolving the feed pretreatment requirements of SCWO. In turn, SCWO resolves the afterburner/PAS requirements of TD by destroying the organics at SCWO conditions and capturing particulates, acids, and any other pollutants in the liquid effluent, and avoiding dioxin formation by rapid quench at the reactor outlet. To integrate the TD and SCWO subsystems, the entire TD-SCWO system operates at elevated pressures of about 500 psig. All the performance advantages of SCWO

persist at this modest subcritical pressure, and bulk solids can be readily contained in a pressurized TD operating at about 500 psig.

Two forms of TD can be utilized, batch and continuous flow. In the batch TD, a batch of solid material, specifically a 55-gallon drum, is placed in a sealed chamber and treated to desorb and discharge any organics to SCWO. In the continuous TD, bulk solids, shredded to size, are lock-hoppered into a screw feeder desorption chamber where organics are desorbed and discharged to SCWO. Quantity and type of feed material will dictate which form of TD to use — batch or continuous. For the SRS application, a 55-gallon drum batch system is favored initially to minimize pretreatment requirements and the potential spread of Pu-238 contamination.

A process flow diagram (PFD) for an integrated TD-SCWO system is shown in Fig. 1. As depicted in Fig. 1, batched solids such as 55-gallon drums are fed into the pressurized (35 atmospheres) batch TD where they are heated to a temperature of 1200°F by heat transfer with injected steam, and from the heated external wall. The atmosphere is overall net reducing, but may contain injected oxidants (oxygen and/or air) that serve as reactants for localized partial oxidation and gasification reactions that assist in overall volatilization of organic contaminants and subsequent transport from the inorganic residues to the SCWO portion of the process for final destruction. The elevated pressure helps ensure access to containerized materials within the drums. The batch TD-SCWO process minimizes handling of the feed material.



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Fig. 1. Batch TD-SCWO process for SRS drummed MTRU wastes

The TD-volatilized contaminants flow into the SCWO portion of the process where they are combined with an excess of oxidant (air or oxygen) and auxiliary fuel and maintained at a temperature of 1200°F for sufficient residence time (10–30 sec) to ensure complete oxidation of all organic species. At SCWO conditions, organic materials and gases become highly soluble in water. This makes it possible to carry out rapid, complete oxidation using water (or steam) as a carrier medium. Typical products from SCWO include carbon dioxide (CO₂), water, and inorganic salts or acids. Liquid effluents can be collected for analysis and verification of waste destruction prior to further processing. The liquid effluent can then be treated via conventional means (such as precipitation, filtration, evaporation, adsorption, and encapsulation) to concentrate, dry, and stabilize inorganic solids, including salts, metals and radionuclides. Gaseous effluents are passed through HEPA and sulfur-impregnated activated carbon filters to remove any trace quantities of particulates, including mercury and other metals or radionuclides, before release to the atmosphere.

A continuous emissions monitoring system (CEMS) is provided for the gaseous effluent in Fig. 1 to monitor and record the release of any traces of carbon monoxide, acid gases, total hydrocarbons, and NO_x. The clean, cool process gases are mixed with the building ventilation airflow, passed through a HEPA/carbon filter bank and ventilation fan, and then released through a monitored stack. A radiation monitoring system measures and documents any trace radionuclides that may pass through the stack. GA expects this to be an SRS monitored stack.

The dry solid residues from the TD and SCWO effluent are over-packed and transferred to high-integrity containers (HICs) and transferred to a shipping package for shipment to the WIPP. The packaged residue is suitable for long-term storage due to its solid, inert, all-inorganic nature.

Depending on the composition, it may be desirable to further stabilize the low-volume solid residue before shipment to WIPP. The final result is a process that can treat a complex mixture of organic wastes, with the solid residues meeting WIPP and TRUPACT-II acceptance criteria.

The intimate gas-liquid contacting in the SCWO reactor ensures that particulates (including metal oxides and radionuclides) and acid gases remain with the liquid effluent, while the scrubbed gases can meet the most stringent environmental regulations. Unlike incineration or other competing technologies, the TD-SCWO process will not produce dioxins and furans as hazardous waste byproducts. The generation of these hazardous byproducts is a major factor fueling the search for alternatives to incineration in the DOE complex and nationally.

SCWO research and development started in the early 1980s at leading universities. GA began its SCWO development program in the early 1990s, and expanded in 1995 with the acquisition of MODAR. SCWO has continued to mature and recently several commercial applications have emerged.

GA has developed solutions for the three major challenges to the development and maturation of SCWO: feed preparation and pumping, salts transport, and control of corrosion. Advanced pumping methods that enable the reliable pumping of a wide range of liquids including heavy slurries and pastes with solids loading up to 40% by weight have been developed. Control of salt plugging is achieved through chemical pretreatment and operational controls. Operational strategies to minimize salt plugging have been demonstrated, including periodic subcritical water flushing of the SCWO reactor to dissolve salt deposits. Corrosion control have been achieved through the use of corrosion-resistant linings (such as platinum or titanium) of the SCWO reactor and heat exchangers. GA has operated its SCWO systems for

many thousands of hours, with severely corrosive feeds, while maintaining excellent control of corrosion.

The combined TD-SCWO process further eliminates the need for an extensive PAS system for TD, and a high-pressure feed pumping system for SCWO. These simplifications will further contribute to the overall maturity of the proposed technology.

PROJECT DESCRIPTION

GA's existing TD-SCWO pilot plant equipment will be configured to closely match the process steps envisioned for the production system as depicted in the process flow diagram shown previously in Fig. 1. GA owns a batch pressurized TD that will be used for this test program. This unit was built and successfully tested on two waste streams: (1) lab refuse (paper/plastic trash) and (2) oily soils. This system will operate in the range of 500 psig with peak temperatures of 1000–1200°F. GA owns a versatile SCWO pilot plant capable of testing various process configurations, including TD-SCWO. Figure 2 shows the reactor skid with preheater and coolers. Anticipated process conditions for the SCWO reaction zone are 500 psig at 1200°F and 10–20 seconds residence time. Gaseous effluents are continuously monitored for O₂, CO₂, CO, H₂, and total hydrocarbons. High-pressure air or oxygen is supplied from a compressor.

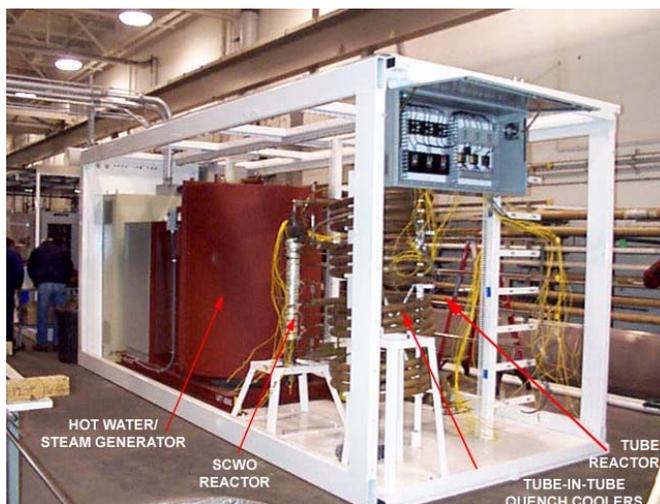


Fig. 2. Reactor skid

During the Phase I Demonstration, modifications are planned to integrate the TD and SCWO subsystems, improve data acquisition and effluent gas stream monitoring/sampling and other improvements needed for a successful demonstration. High-efficiency particulate (HEPA) filters and sulfur-impregnated activated carbon filter canisters will be installed after the gas pressure letdown valves to efficiently capture any residual particulates, metals and/or mercury from the gaseous effluent. High-efficiency filters and sulfur-impregnated activated carbon filter canisters will be installed after the liquid pressure letdown valves to efficiently capture any residual particulates, metals and/or mercury from the liquid effluent. The batch TD will be moved adjacent to the SCWO pilot plant to minimize interconnecting piping lengths, especially for the heated flow of desorbed organics from the batch TD outlet to the SCWO reactor inlet. The preliminary design time/temperature profile for the batch TD-SCWO system is shown in Fig. 3.

A subscale drum-like container of surrogate waste will be loaded into the batch TD, sealed, pressurized, and heated to temperature by external heaters and injected steam. Thermally desorbed organics flow from the TD to the SCWO system, where excess oxidant and auxiliary fuel are added to insure complete oxidation of the organics. Effluents from the SCWO system are treated by filtration, and released (gas) or sampled and shipped to waste disposal (liquids).

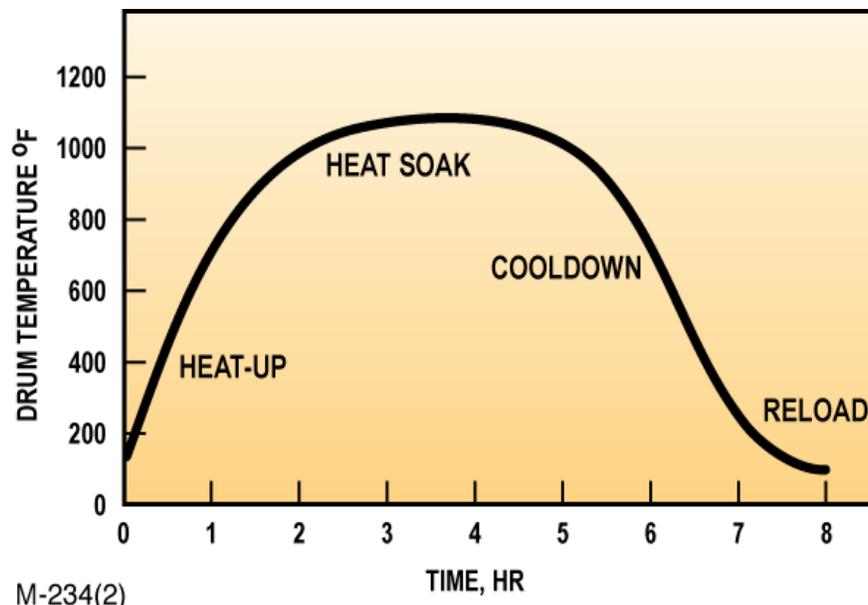


Fig. 3. Typical batch pressurized desorber time/temperature profile

Three surrogate waste blends have been identified that cover the limits of the MTRU waste composition in the solicitation. They are as follows:

- Surrogate #1 — high organic level — cans or bottles of liquid (acetone, etc.), rubber gloves (leaded, non-leaded), cellulose (mops, coveralls, wood, Kraft paper)
- Surrogate #2 — high inert level — metal pieces, sheet rock, concrete, sand, resins
- Surrogate #3 — high plastics/CI level — PVC pipe, bags, valves, shoecovers, fiberglass

Each surrogate waste stream will be spiked with organics (1% each CCl_4 and C_2Cl_4) and metals (1% each elemental lead and mercury) to determine destruction and removal efficiencies in the TD-SCWO systems. Cerium oxide powder will also be added to each waste stream as a surrogate for plutonium oxide.

Analysis of the data contained in the solicitation indicates that while each drum can have characteristics that are bounded by the three surrogates listed above, the average concentrations of all drums (which provides insight as to total thermal load for the wastes) are listed in Table 2.

TABLE 2 AVERAGE MTRU WASTE CONCENTRATIONS			
Item	Average	Item	Average
PVC	18%	Metals (CS,SS,Sb,Cu,Pb)	10%
PE/PP	8%	Cd sheet	2.5%
Cellulose	23%	Pt wire	2.5%
Rubber gloves (with lead)	17%	Ceramics (glass, sand, concrete)	11%
Misc Organic Chemicals	3.5%	Resins	2.5%
CaO	2%		

A baseline test, followed by a series of nine single-variable parametric tests (Table 3) will be performed to vary key independent variables to assist in selection of operating conditions for subsequent TD-SCWO optimization tests.

TABLE 3 SINGLE-VARIABLE PARAMETRIC TESTS OF BATCH TD-SCWO		
Variable	Baseline Condition	Parametric Condition for this Test (all other conditions at baseline)
Treatment time	8 hr	±4 hr
Desorber/SCWO pressure	500 psig	1000 psig
Desorber temperature	1200°F	±200°F
Desorber steam flow	4 lb/hr	±2 lb/hr
SCWO excess oxygen	20 vol %	±10 vol %
SCWO residence time	20 sec	±10 sec
Waste surrogate type	Each surrogate	Each surrogate

A computerized data acquisition system will record key data for subsequent analyses. In addition, effluent gas will be monitored continuously for O₂, CO₂, CO, and hydrocarbons. Effluent liquids will be analyzed for Total Organic Content. Surrogate feed composition will be determined via standard laboratory Ultimate Analysis. Success will be measured by (1) attainment of hydrogen reduction goals, (2) meeting environmental criteria for processed waste and effluents, and (3) equipment operability at the specified conditions.

A series of optimization tests will then be run for each surrogate to determine optimum processing conditions. A final series of three demonstration tests will be run with fixed conditions for each of the three surrogates.

PRIOR RESULTS

GA's proposed TD-SCWO is a new process based on two well-established technologies — TD and SCWO. The combined process TD-SCWO has no prior uses. However, there are many examples of prior use of traditional TD and SCWO. Typical treatment results achieved in numerous TD and SCWO applications are summarized in Table 4.

A pressurized batch TD was constructed and tested at GA to demonstrate the process for volatilizing organic compounds from contaminated solids. The objective was to remove the organics from the solids and produce an effluent gas stream that could be fed to a SCWO reactor for final destruction. The system was designed to operate at a pressure of about 500 psig and a temperature of about 1200°F. The basic design of the batch TD rig is shown in Fig. 4. A photograph of the assembled test rig is shown in Fig. 5.

Two types of solid samples, hydrocarbon contaminated soil, and simulated laboratory waste were tested. The first sample type, hydrocarbon-spiked soil, consisted of soil from the GA site blended with 5 wt % motor oil. This mixture resulted in a composition of about 4.3 wt % carbon and 0.7 wt % hydrogen. The second sample type was made up by blending a mix of typical laboratory waste items such as plastic-ware, paper and cloth wipes, filters, cardboard, wood,

**TABLE 4
TD AND SCWO PERFORMANCE COMPARED TO REGULATORY STANDARDS**

Effluent Emissions	Regulatory Requirements ⁽¹⁾	TD Performance ⁽²⁾	SCWO Performance ⁽³⁾ (no gas cleanup devices)
Dioxins/difurans, ng/DSCM (TEQ)	<0.2	<0.015	<0.006
Particulate Matter, mg/DSCM	<34	<10	<4
Toxic Metals, mg/DSCM	<0.24 for Cd+Pb <0.097 for Sb+As+Be+Cr	<0.003 for Cd (no data for Pb) <0.003 for As+Be+Cr (no data for Sb)	<0.015 for Cd+Pb <0.015 for Sb+As+Be+Cr
Destruction and removal efficiency, %	>99.99	99–99.9999	>99.999
HCl, ppmv	<21	<10	<0.4
NO _x , ppm	Typically <100 ppm	<100	<10
CO, ppm	<100	<20	<2
Hydrocarbons, ppm	<10	<5	<0.03 (with organic waste)
Residual solids meet Land Ban Criteria	Organic TCLP values	Yes	Yes

Notes: (1) Regulatory requirements include MACT and Land Ban Criteria.
 (2) "Comparative Analysis and Evolution of Different Thermal Desorption Technologies — A Manufacturer's Point of View," IT3 Conference, Portland, Oregon, May 2000.
 (3) "Update on Hydrothermal Oxidation Developments on DARPA/ONR and Air Force Projects at General Atomics," IT3 Conference, Portland, Oregon, May 2000.

styrofoam and inert alumina beads. The objective was to create a sample with approximately 15 wt % organic-based material and the balance inert alumina. A stainless steel basket was used to facilitate installation and removal of the samples from the TD.

Following a half hour purging with nitrogen to remove air, the TD was pressurized to 500 psig, and the heating system set for 1200°F with a low flow of nitrogen. When the TD temperature reached 800°F, the water/steam injection system was activated. The samples were subjected to 500 psig at 1150–1200°F for a total exposure time of 3 hr before depressurization and cooldown.

After cooldown, the treated samples were removed and sealed for total carbon and hydrogen analysis as a measure of hydrocarbon destruction. The results of the total C/H analysis are summarized in Table 5.

The hydrocarbon-spiked soil analysis (before treatment) compared favorably with the theoretical H/C ratio (4.3% C, 0.7% H). The analysis for the treated soil samples indicated that both the carbon and hydrogen were substantially (91.1%, 93.1%) depleted. Since both C and H were depleted in approximately equal amounts, the removal mechanism was primarily volatilization rather than thermal decomposition that would be expected to leave a significantly higher C residue.

For the simulated laboratory samples the results were significantly different. Again there was substantial depletion of hydrogen but with little loss of carbon. However, the treated sample analysis indicated approximately 50% higher C content than the untreated original sample. Thus, starting with H/C solids, the depletion mechanism was more likely thermal decomposition, leaving a substantial carbon residue. The treated sample C-H analysis was calculated to be 87.6%.

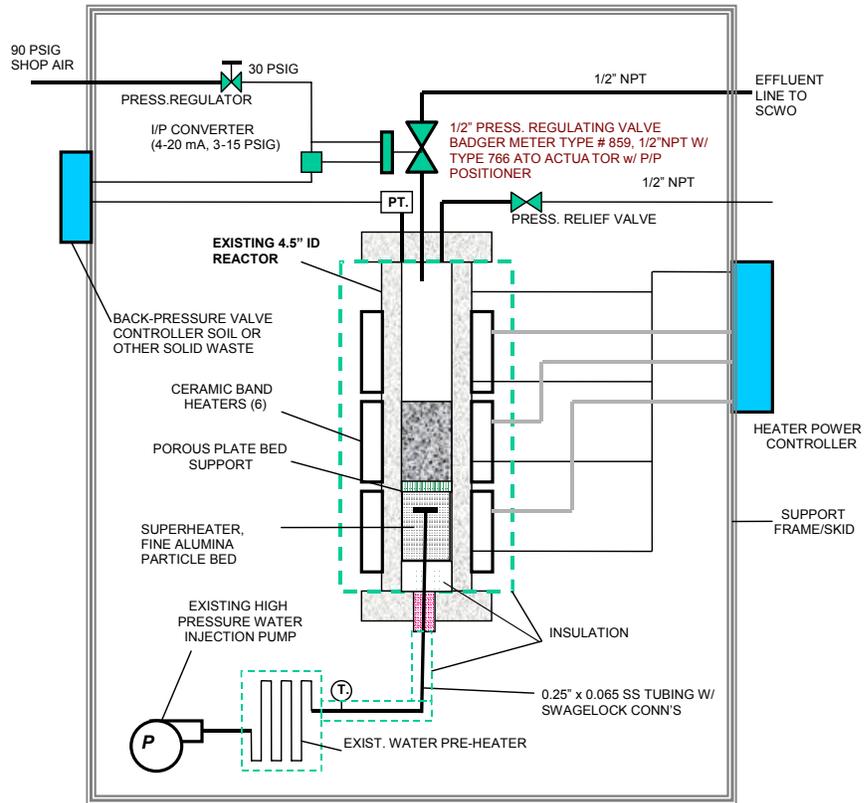


Fig. 4. Pressurized batch TD test system

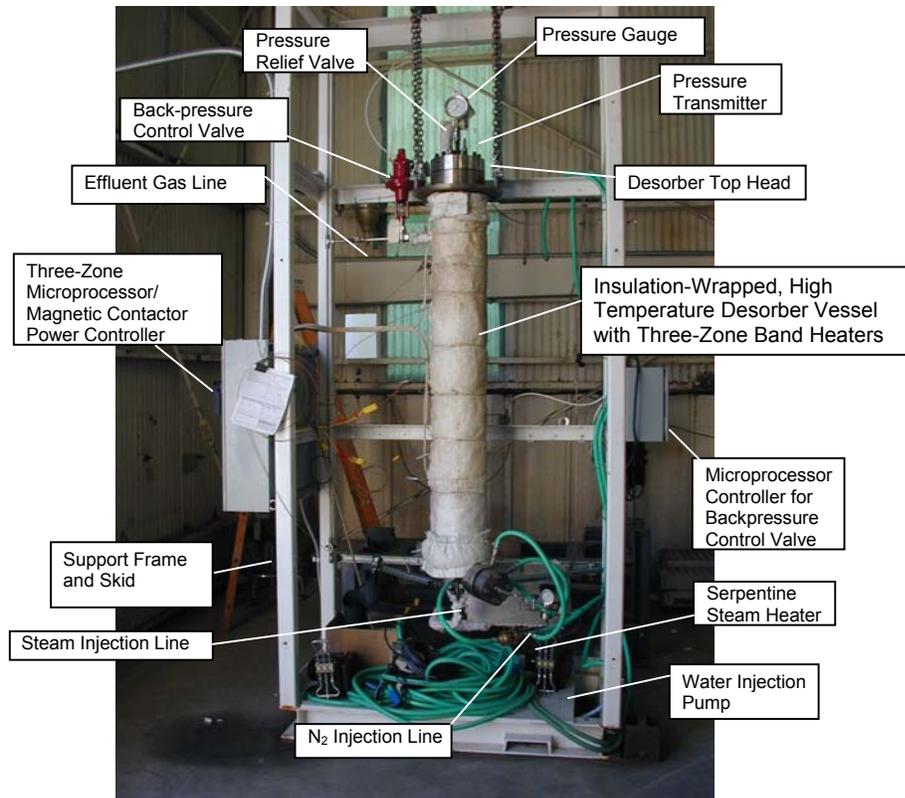


Fig. 5. Pressurized batch TD system

TABLE 5 SUMMARY OF SAMPLE TOTAL CARBON AND HYDROGEN ANALYSIS ⁽¹⁾			
Sample Identification	Carbon (wt %)	Hydrogen (wt %)	Reduction in H (%)
Initial (untreated) soil	4.52	0.58	—
Post-test (treated) soil	0.40	0.04	93.1
Initial (untreated) lab waste	10.11	1.93	—
Post-test (treated) lab waste	10.11	0.24	87.6

Note: (1) Total carbon and hydrogen analysis per ASTM method D 5373-93.

The batch TD unit operated in a smooth and stable manner with no observed excursions. Two simulated solid wastes, hydrocarbon soil and laboratory waste, were treated and analyzed for an estimate of hydrocarbon destruction. The destructive removal efficiency was on the order of 90%. Thus, not surprisingly, GA has shown that TD is an effective method of removing organics from bulk solids. More importantly, GA has demonstrated proof-of-concept for a pressurized TD that is compatible with further treatment by direct feed to SCWO. During this testing, many technical issues for a pressurized TD (pressurization, purging, steam feed, heating rate and process stability) were resolved, and plug-free desorption and transport of the organics (similar to those in the SRS MTRU wastes) was demonstrated. The next step is to demonstrate pressurized TD of the organics in a subscale drum-like container with access only from the top, followed by organic feed and destruction in an integrated SCWO system. This is the proposed approach for the Phase I Cold Demonstration Test.

BENEFITS

The potential benefits of TD-SCWO are described below.

Lower Life Cycle Costs. Life Cycle Costs (LCCs) for the SRS MTRU application are dependent on numerous issues related to the SRS site, and not readily known by GA or other respondents. Factors such as the degree of remote operation and maintenance to be used; ready access to remote handling equipment, and the versatility of that equipment; available space for equipment installation within existing facilities, and the number of operating units required to achieve disposal operations within schedule constraints; number of shifts per day and days per week of operation; degree of drum unpack and repack required; and other logistics issues that effect LCCs. Given these uncertainties, and the differing impacts they will have on various technologies, GA offers the following qualitative perspective.

- TD-SCWO will require less gas treatment technology than any known competitive technology due to the internal scrubbing achieved by SCWO. At most, a chiller, activated carbon and HEPA filters will be required to capture mercury and other trace contaminants.
- TD-SCWO is extremely compact, requiring less footprint than any known competitive technology due to the higher throughput achieved at elevated pressure and smaller gas cleaning system.

- Reduced carryover of Pu-238 from the batch TD to SCWO may enable the SCWO system to be contact-maintained — a potentially significant advantage over competing technologies.
- For nonradioactive applications, GA has performed LCC analyses, which have generally compared favorably with incineration for the same waste feed.

Lower Health and Safety Risks to the Worker and the Public. TD-SCWO is a sealed, pressurized system with the pressurized components enclosed by secondary containment and vented through HEPA filters and activated carbon. In the event of process upsets, relief valves open to discharge the system contents to a dump tank for reprocessing at a later date. All maintenance operations are performed on the depressurized system. Effluents are monitored continuously to ensure that they meet all regulatory standards. Leading indicators of process performance are also tracked by the process control computer system to provide ongoing assurance of stable operation.

Lower Risks for Detrimental Impact to the Environment. TD-SCWO is an inherently clean process that eliminates the conditions that lead to *de novo* synthesis of dioxins or furans. TD-SCWO will minimize emissions of the metals and radionuclides that are currently in the drummed wastes by retaining most of these wastes in the TD, and capturing the remainder in the SCWO liquid effluent.

Reduced Quantity of Waste Materials Requiring Disposal. TD-SCWO will densify the wastes allowing repackaging into fewer drums for transport to WIPP. Solid effluents from SCWO (obtained by filtering and drying the SCWO liquid effluent) will generally be lower in volume than for any other technology, because TD-SCWO mineralizes all organic feeds to CO₂, water, and mineral salts. This will maximize the volume reduction and minimize the resultant residues to be disposed.

Reduced Amount of Secondary Waste Generated. Because TD-SCWO does not produce dioxins or furans, no activated carbon is required to meet the stringent new MACT standards for dioxin and furan emissions. Mercury emissions will be collected on activated carbon filters (sulfur impregnated to fix the mercury in an insoluble form) and will be disposed of as a stabilized hazardous waste. TD-SCWO is expected to generate less secondary waste than competitive technologies. With the exception of mercury, metals including radionuclides and other particulates will be retained within the TD-SCWO system and will not add loading to the backup HEPA filters, thus reducing the frequency of replacement of these filters. Solids are discharged from the batch TD along with the other drum residues, and are filtered out of the SCWO liquid effluents for subsequent drying and disposal. Salts crystallized from SCWO liquid effluent (primarily NaCl from PVC processing) will be recombined with the main process solids discharge and repackaged for transport to WIPP. Here, again, TD-SCWO should produce less secondary waste than other competitive technologies because of the simpler gas cleaning process.

Reduced Hazard Level and Category of Waste. TD-SCWO will efficiently destroy all organic constituents in the waste. Metals (except mercury) and radionuclides will be retained with the bulk desorbed waste and will be repackaged for disposal at WIPP. Mercury will be retained on sulfur-impregnated activated carbon for off-site disposal. Remaining metals may prevent the residue from meeting the Land Disposal Ban, as measured via Toxic Characteristic Leaching

Procedure (TCLP) testing, and further stabilization may be required. Most importantly, TD-SCWO will not generate any dioxins or furans, which is less likely for competitive technologies which do not eliminate the conditions that lead to *de novo* synthesis of dioxins and furans.

Possesses Ability to Meet Regulatory Requirements. TD-SCWO inherently meets all regulatory criteria under the Clean Air Maximum Achievable Control Technology (MACT) rules. This includes destruction of organic compounds, retention of metals within the process, and all emissions within regulatory standards, including particulates, HCl, SO_x, NO_x, and CO, and again, dioxins and furans. Competitive technologies are less likely to meet all regulatory requirements without extensive additional pollution abatement equipment. RCRA permits have been obtained for three of GA’s SCWO systems in record time, attesting to the degree to which the technology meets regulatory requirements.

FUTURE ACTIVITIES

Following successful completion of Phase I, GA plans to perform Phase III and Phase IV testing at a suitable DOE site, and then to design, build, and operate a full-scale system to treat actual wastes at the SRS site.

Following verification of scale-up parameters, the 1/5th scale system will be designed to the parameters shown in Table 6. A 1/5th-scale batch TD-SCWO system is sized to process a 55-gallon drum of waste in about 8 hr.

TABLE 6 1/5 TH -SCALE TD-SCWO DESIGN PARAMETERS	
Design Parameter	Value
Batch TD waste volume	55 gallons
Batch TD dimensions	26” ID x 4 ft tall
SCWO heat release	360,000 Btu/hr
SCWO oxygen demand	65 lb/hr
System pressure	500–1000 psig
System temperature	1000–1200°F

GA’s full-scale TD-SCWO concept for the SRS application is focused at processing whole 55-gallon drums. The full-scale production system will consist of five modular 1/5th-scale TD-SCWO systems that can process 5 drums of waste simultaneously, twice per day. Thus, the full-scale system can process 10 drums per 2-shift day, and 2,500 drums per 250-day year. An inventory of about 5,000 drums can be processed in about 2 years of full-scale operations.