Innovative Technology Summary Report

Plasma Hearth Process

Mixed Waste Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

Plasma Hearth Process

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Mixed Waste Focus Area

Demonstrated at
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Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://OST.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Technology Summary

The Plasma Hearth Process (PHP) is a high-temperature thermal process, which has been adapted from a commercial metallurgical technology, for the treatment of mixed waste. A PHP heats waste to a temperature such that the waste is converted into a molten form that cools into a stable glassy and/or crystalline waste form. Hazardous organics are destroyed through combustion or pyrolysis during the process and the majority of the hazardous metals and radioactive components are incorporated in the molten phase. The PHP chamber temperature is approximately 593 – 704°C and PHP melt temperatures are in the range of approximately 1,650 – 2,200°C. The PHP has a state-of-the-art, air pollution control system (APCS) to remove particulates and volatiles from the offgas. The advantage of the PHP is that it is a single, high-temperature thermal process that minimizes the need for multiple treatment systems and for extensive sorting/segregating for large volumes of waste. The PHP has the potential to treat a wide range of wastes, while minimizing the need for sorting, reduce the final waste volumes, produce a leach resistant waste form, and destroy organic contaminants.

One feature of the PHP is its ability to process unopened waste containers such as 55-gallon drums. This has the potential to greatly minimize the handling, personnel exposures, and secondary wastes created when waste containers are opened. Inorganic material is melted and collected in the fixed hearth where it separates by gravity into slag and molten metal layers. Oxidized materials, including actinides and nonvolatile heavy metals, tend to migrate to the slag layer. The organic fraction is partially combusted and pyrolyzed, then ducted to a secondary-combustion chamber where it experiences a high-temperature environment and is contacted with excess air and a methane flame to complete the combustion. A series of baghouse filters, carbon filters, and high-efficiency particulate air (HEPA) filters are then used to remove particulate and gaseous contaminants from the offgas before release from the stack.

Three melter systems were constructed and tested between 1993 and 1997: Nonradioactive Bench-Scale system (NBS), Radioactive Bench-Scale System (RBS), and Nonradioactive Pilot-Scale System (NPS) (see Figures 1 and 2). The melters were developed by Science Applications International Corporation (SAIC) in cooperation with Retech, Argonne National Laboratory-West (ANL-W), and Lockheed Martin Idaho Technologies Company (LMITCO).

Nonradioactive Bench-Scale System

The NBS is located at the SAIC Science and Technology Applications Research (STAR) Center in Idaho Falls, Idaho. This is a batch system with a nominal feed rate of 15 pounds per hour with a refractory lined fixed hearth vessel equipped with a 150 kilowatt Retech RP75T transferred arc plasma torch. Four categories of testing were completed in this system: (1) secondary waste stream treatability, (2) operability, (3) potentially difficult to treat waste stream treatability, and (4) refractory performance testing. These data were used to validate the PHP design model and to predict the behavior of the RBS and NPS systems.

The NBS system is owned and operated by SAIC and remains at the STAR Center to support any future development or deployment efforts. It is currently being used by SAIC for a variety of nongovernment thermal treatment experiments.

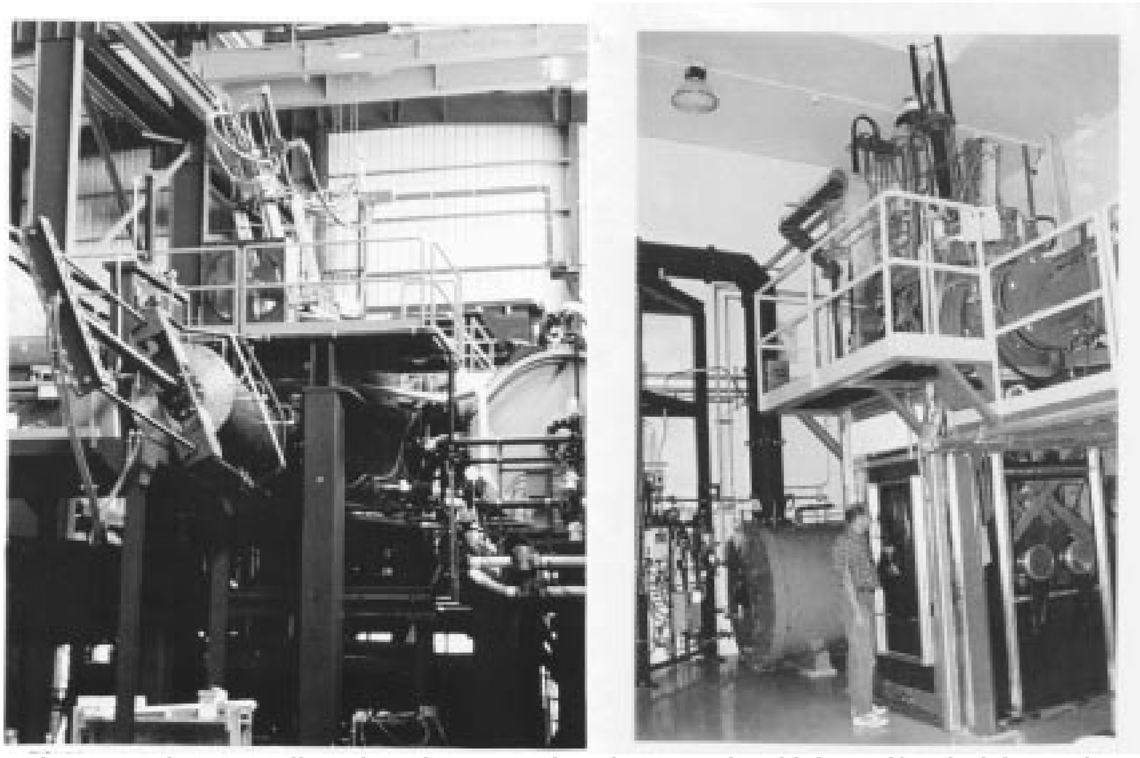

Figure 1. The Nonradioactive Pilot-Scale (NPS) system in Ukiah, California (pictured at left) and the Radioactive Bench-Scale (RBS) system at Argonne National Laboratory-West (ANL-W) (pictured at right) (Leatherman et al. 1995).

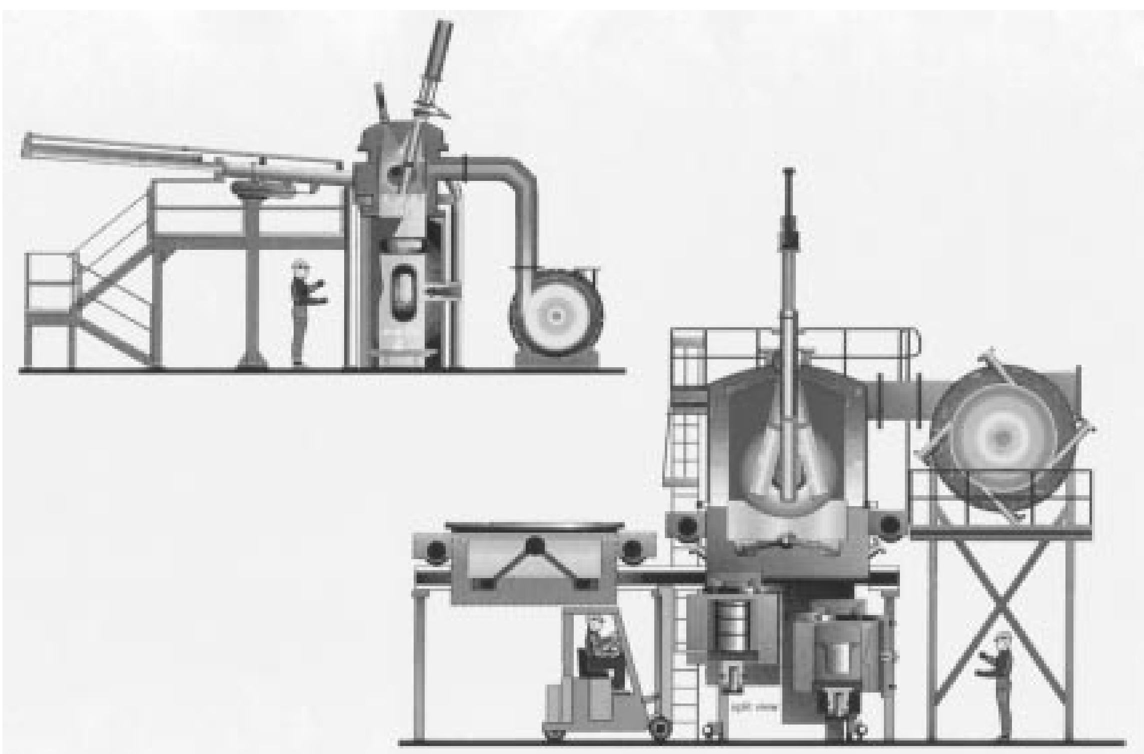

Figure 2. Comparison between the Radioactive Bench-Scale (RBS) (left) and the Nonradioactive Pilot-Scale (NPS) melters (right) (Leatherman et al. 1995).

<u>Radioactive Bench-Scale System</u>

The RBS system, owned by DOE and operated by ANL-W, is located at ANL-W's Transient Reactor Test

Facility at the INEEL. The RBS system is a batch system with a nominal feed rate of 30 pounds per hour. The RBS plasma chamber is 34 inches with a mean height of about 36-inches (the head is domed) and is equipped with a 150 kilowatt Retech RP75T transferred arc plasma torch. The batch feed system holds eight, 1-gallon waste containers. The RBS melter includes a full offgas and APCS. The purpose of the RBS demonstration program was to evaluate, in a reduced-scale system, the behavior and fate of radionuclides and assess the performance of this technology in a radioactive environment.

Nonradioactive testing only, using radionuclide surrogates, was completed in this system. The MWFA directed the RBS project not to initiate PHP radioactive testing in FY-97. There were two reasons for this decision: (1) the privatized waste treatment contract at INEEL will not be using this technology and no other end users have been identified and (2) with a reduced FY-98 budget, decontamination and decommissioning costs could not be justified for the limited data that could have been acquired in FY-97.

The MWFA issued an Expression of Interest to all DOE Technical Program Officers for relocation and utilization of the RBS system. A proposal was received from ANL-W and the DOE-Chicago office to potentially use the system in several proposed development efforts. The MWFA awarded the system to ANL-W in FY-98.

Nonradioactive Pilot-Scale System

The NPS system, owned by DOE and operated by SAIC and Retech, is located at the Retech facility in Ukiah, California. The system consists of a 6.5-foot by 6.5-foot cylindrical hearth equipped with a 1.2 megawatt Retech RP600T plasma torch. The system is capable of being continuously fed with a nominal feed rate of between 1,000 – 1,500 pounds per hour depending on the feed matrix. The feed system holds three, 55-gallon waste drums at a time, and includes a full offgas and APCS. The pilot-scale system is capable of separating the final waste form into the product slag and metal phases by the use of a tilt/pour hearth system. The goal of this facility was to prove the feasibility of the PHP technology by treating waste in a full-scale PHP system. The system was to be used to complete the process engineering development, further demonstrate environmental compliance, study surrogate radionuclide behavior, and evaluate long-term operability.

The disposition of the NPS system has not yet been decided. The NPS system development and testing was supported through a DOE/SAIC Cooperative Agreement in FY-97. The agreement covered NPS Readiness Preparation, Testing Operations, RBS/NPS Companion Testing, and NBS/NPS Companion Testing. The DOE has extended the Cooperative Agreement through FY-98 to support SAIC in identifying an end user for this system. As part of this marketing effort, SAIC has prepared a conceptual design of a PHP Production Waste Treatment Facility. The design was based on the NPS system, with upgrades for enhanced operation, with regard to throughput and hardware configuration, and on the RBS system with regard to radiological factors (such as partitioning of radionuclides and design features that address radiation safety). At the end of FY-98, DOE will decide on the disposition of the NPS equipment.

Demonstration Summary

A high-temperature melter strategy was developed by the MWFA. SAIC then developed and the MWFA approved an experimental program to verify the capability of the PHP process to treat mixed wastes to meet waste disposal facility acceptance criteria. The experimental program focused on: (1) determining the partitioning of actinides, other radionuclides, and hazardous metals, (2) destroying volatile organic materials and Resource Conservation and Recovery Act (RCRA) listed hazardous constituents, (3) the performance of the final waste form (product), and (4) the operating characteristics of the process.

Experimental melter testing included surrogate correlation/similitude testing. There were two aspects to the surrogate correlation and similitude testing. The first was to understand how well surrogates mimic the behavior of plutonium during melter processing. For example, if the behavior of a surrogate like cerium is well understood and can be correlated to the behavior of plutonium, then future melter development and validation testing can be conducted using cerium instead of plutonium. Cerium is nonradioactive and is

safer, easier, and less costly to work with than plutonium. Validation that cerium behaves like plutonium would greatly reduce the complexity and cost of melter testing while increasing the safety aspects.

The second aspect of surrogate and similitude testing was to determine how plutonium behaves as a function of melter size and scale-up, so that assurances about plutonium behavior in full-scale melters could be gained. The same discussions apply and are no less important for the other radioactive and hazardous components in the waste.

Initial testing was carried out in the NBS system. Test results demonstrated that mass balance closure was difficult to obtain with this system configuration. The RBS system was then designed to provide better mass balance closure and to perform radioactive tests to validate the use of cerium as a surrogate for plutonium. To evaluate partitioning behavior under more "production-like" conditions, the NPS system was designed as a continuously operated system (NBS and RBS are both batch systems). The purpose for testing this system was to identify radionuclide surrogate and hazardous metal partitioning in a continuously operating, full-scale system, determine organic destruction efficiencies, and evaluate waste form performance and system operating characteristics. These data were to be correlated to the actual radionuclide data collected from the RBS system. Based on data collected through the PHP program, life-cycle cost and performance data and maintenance requirements were evaluated.

<u>Partitioning Experiments</u>
Experiments in the NBS system used manufactured surrogate wastes having compositions that simulated actual wastes in the INEEL stored alpha-low-level waste (LLW) and transuranic (TRU) waste inventory. The experimental program used nonhazardous simulated wastes, and eventually included the following hazardous metals: arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, and silver.

The RBS system initiated testing with a series of surrogate wastes. Cerium validation tests were supposed to be performed and compared to real waste tests. In addition to cerium, a stable isotope of cesium chloride was used and the hazardous metals arsenic, barium, beryllium, cadmium, chromium, mercury, nickel, lead, silver, and selenium were used. The real waste tests were eliminated in FY-97 when the INEEL privatized their waste treatment and it was determined that the PHP technology would not be part of the process. With no identified end user and reduced technology development budgets, the MWFA cancelled the radioactive test series to reduce mortgage costs associated with decontamination and decommissioning of the system. The project continued partitioning tests with radionuclide surrogates and hazardous metals.

The NPS system testing did not reach the stage to evaluate metals partitioning. The investigators learned midway through FY-97 that they would not be allowed to spike the feed with hazardous metal at the Ukiah facility, due to state regulatory issues.

<u>Organic Destruction</u>
In the NBS system, the organic sludge feed contained the following organic components: heavy oil, parts cleaner solvent, trichloroethane, tetrachloroethylene, and polyethylene baggies. The organic waste feed used for the RBS tests had the following organic constituents: styrene resin, trichloroethylene, and motor oil. The NPS system ran a limited source test with a feed stream containing polyvinyl chloride and high-density polyethylene.

<u>Waste Form Performance</u>
Waste form performance tests were run on samples collected during most of the NBS tests and all of the RBS and NPS tests.

<u>Operating Characteristics</u>
Feed variability testing focused on understanding how variations in the melter feed composition would affect performance. For example, a melter is operating successfully on a debris feed comprised primarily of job control waste. If a feed consisting primarily of scrap metal is suddenly introduced, how is the volatility of the radionuclide and hazardous components in the melter affected and how will the performance of the offgas system be impacted? This type of information is needed to fully understand the capabilities and limitations of the melter technology. The operating characteristics of each system during all experimental testing were recorded. The data may be used to support future similitude and correlation testing, and future system design.

Key Results

Key issues addressed through these projects were the distribution of radionuclide surrogates and hazardous heavy metals throughout the system, leaching performance of the final product, and operational characteristics of the PHP with various waste feeds. Surrogates were to have been evaluated for their validity in accurately representing the behavior of plutonium, but this testing was cancelled due to no identified end user for the data and reduced budgets. Experiments were designed to determine the major effects of processing feed materials in terms of organic-carbon content, silica and calcium content, and oxidizing conditions within the plasma chamber. The project major accomplishments include:

Thirteen nonradioactive experiments (in 20 operations) were carried out in the RBS system.

400 hours of operation were completed in the PHP pilot-scale system, including two continuous 100-hour test runs. Torch electrode life in excess of 80-hours was achieved.

Cerium oxide (plutonium oxide surrogate) was found to primarily partition to the vitreous slag. Slightly higher retention rates were noted for sludges as compared to combustible debris wastes.

All high vapor pressure hazardous metals (Hg, Cd, and Pb), except barium, partitioned to the offgas system, where they were removed before release out the stack.

Slag samples passed the Environmental Protection Agency's (EPA's) Toxicity Characterization Leaching Procedure (TCLP) with a comfortable margin. This margin was reduced, particularly for Cr, Cd, and Pb, when compared to the proposed Universal Treatment Standards (UTSs).

Homogeneity of the molten pool in the RBS system was poor for several of the tests. This was partially attributed to high melt viscosities. Initial NPS test results indicated a homogeneous melt was obtained.

Dispersion of cesium throughout the system was noted. High calcium wastes created slags that exhibited the poorest retention of cesium.

Total particulate stack emissions were one-to-two orders of magnitude below EPA allowables, despite evidence of dry particulate carryover from the acid-scrubber.

Except for mercury, stack emissions of metals, diatomic chlorine, and HCl were either near or below limits of detectability.

Deliberate and inadvertent water leaks in the RBS process showed that the system appears to be safe to steam explosion, with no release of hazardous contaminants to the environment.

A wide variety of waste types have been processed on a small scale.

It has been demonstrated that there is a need for at least some amount of feed characterization, both radiologically and chemically. These radiological constraints would be primarily health physics related. The chemical constraints are primarily related to regulatory emissions requirements, although there is a potential for operational difficulties with certain waste streams.

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SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

A conceptual design for a PHP production waste treatment facility was completed in FY-98 and is shown in Figure 3. A conceptual system would be designed to treat whole, unopened, 55-gallon drums of LLW, mixed low-level waste (MLLW), mixed transuranic waste (MTRU) and hazardous waste materials. The waste drums would be assayed for compliance to the facility's Waste Acceptance Criteria and placed in segregated storage before treatment. A drum conveyor/ loading system would move the waste drums from storage and load them into the transfer chamber. The drums would then be transferred to the feed chamber where they will be fed in a slow, controlled manner into the plasma chamber.

The plasma chamber is where the primary processing of the entire drum and its contents will take place. Within the plasma chamber, the organic constituents of the waste will be volatilized, pyrolized, and/or combusted while the metals and other inorganic materials are incorporated into a molten pool in the crucible. The molten pool will consist of both metallic and vitreous phases, which may be removed separately. The PHP uses a tilt-pour methodology to collect the product. A weir is included in the system to separate the metallic and vitreous phases. The offgas from the plasma chamber will be ducted to a secondary chamber where it will be contacted with excess air and a natural gas flame. While in the secondary chamber, the offgas will be combusted and retained for at least 2 seconds at ⊇1,204°C. These conditions in the secondary chamber will ensure the complete destruction of all organics present in the plasma chamber offgas.

After exiting the secondary chamber, the offgas will be immediately quenched to approximately 204°C in an evaporative cooler. The offgas will then enter a baghouse for removal of the larger particulates, followed by a carbon filter to remove the volatilized mercury and a HEPA filter bank for removal of the fine particulate. After exiting the HEPA filter bank, the offgas will be saturated in a full quench and passed through a packed bed scrubber for removal of the acid gases. The clean, saturated offgas will be demisted and reheated to well above its saturation temperature before passing through the induced draft fan. After the induced draft fan, the offgas will either be recirculated back into the process or exhausted to the atmosphere.

The throughput and volume reduction average for the conceptual treatment facility is given in Table 1. The throughput and hardware design data for the conceptual system were based primarily on the NPS system, with upgrades for enhanced operation. Radiological factors, such as radionuclide partitioning and radiation safety features, were based on work on the RBS system. The data listed in Table 1 are averages. Each waste stream's characteristics will affect the throughputs and volume reduction numbers.

One of the main secondary waste streams of the PHP is flyash, which is captured from the baghouse. Based on preliminary data, flyash generated by the process can, to a large extent, be treated by processing the waste stream in the PHP.

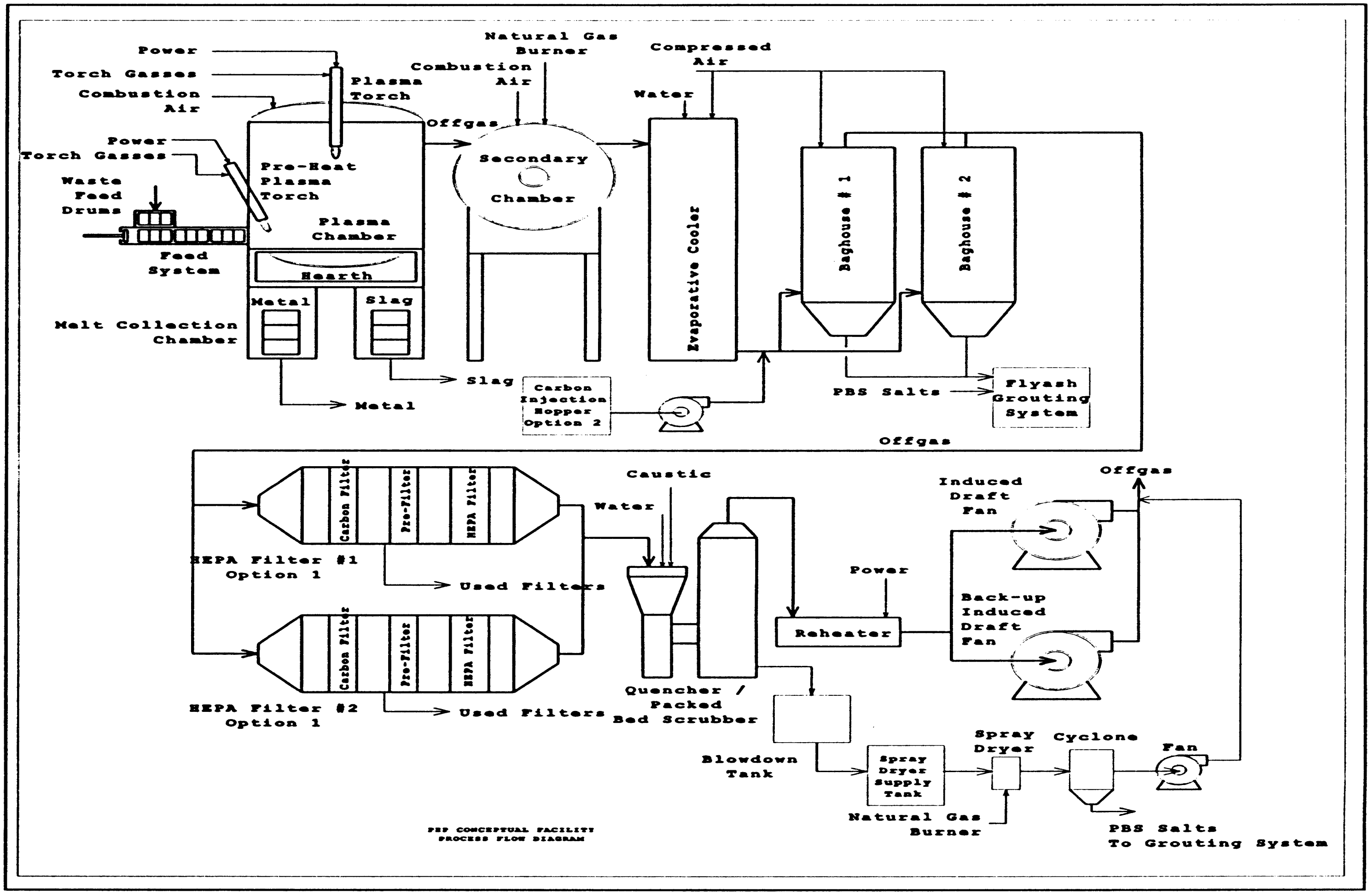

Figure 3. Conceptual Plasma Hearth Process (PHP) Production Waste Treatment Facility.

Table 1. Conceptual Plasma Hearth Process (PHP) process parameters

Result	Parameter
Waste Throughput	1,000 lb/h
Mass of Feed Drum	~ 400 lb
Drum Throughput (55-gallon drums)	2.5 drums/h
Life of Crucible	300 h
Waste/Slag Volume Ratio	5:1
Waste/Metal Volume Ratio	20:1
Waste/Flyash Volume Ratio	30:1
Secondary Waste Streams	
Hearth Refractory	~150 drums/yr
Flyash	~50 drums/yr
Dry Blowdown Salts	~50 drums/yr
System Availability for Processing (after maintenance)	80%
Torch Gas	N_2
Secondary Combustion Chamber Fuel	Natural Gas
Electrical Substation Power Requests.	3,200 kW
Design Life of System	15 yr

SECTION 3

PERFORMANCE

Demonstration Plan

A high-temperature melter strategy was developed by the MWFA. SAIC then developed and the MWFA approved an experimental program to verify the capability of the PHP process to treat mixed wastes to meet waste disposal facility acceptance criteria. The program focused on: (1) determining the partitioning of actinides, other radionuclides, and hazardous metals, (2) destroying volatile organic materials and RCRA listed hazardous constituents, (3) the performance of the final waste form (product), and (4) the operating characteristics of the process.

Testing was focused on INEEL type waste streams: both debris and sludges. These wastes are fairly representative of wastes stored throughout the DOE complex. Work was distributed amongst the three-melter systems appropriately:

- The NBS system would gather data in four areas: (1) secondary waste stream treatability, (2) operability, (3) potentially difficult to treat waste stream treatability, and (4) refractory performance testing. These data were used to validate the PHP design model and to predict the behavior of the RBS and NPS systems.

- The RBS system would complete tests to evaluate the behavior and fate of radionuclides and assess the performance of this technology in a radioactive environment.

- The NPS system would prove the feasibility of the PHP technology by treating waste in a full-scale PHP system. The process engineering development would be completed along with further environmental compliance demonstration, surrogate radionuclide behavior studies, and long-term operability evaluation.

Treatment Performance

Throughput averages for the developmental PHP systems are given in Table 2. The data presented on the developmental systems are averages measured from experimental testing.

Table 2. Plasma Hearth Process (PHP) process results

Result	STAR Center System	RBS	NPS
Waste Throughput	15 lb/h batch	30 lb/h batch	1,000 lb/h continuous
Mass of Feed Drum	~1,000 – 5,000 g/can[a]	~3,500 – 5,000 g/can[b]	~300 lb/drum[c]
Drum Throughput	20 min/can	30 min/can	2.5 drums/h
Life of Crucible	N/A	N/A	300 h

a. 1-quart cans.
b. 1-gallon cans.
c. 55-gallon drums.

<u>Nonradioactive Bench-Scale Testing</u>
Demonstration of the PHP technology to treat mixed waste began with nonradioactive testing in the NBS system at the STAR Center. Several treatability studies were completed in the NBS system (Leatherman et al. 1995). A summary of these tests is listed below. Table 3 lists these tests and provides a short summary of results.

- Ability of the PHP system to treat the fly ash, generated in the APCS. A test objective was to determine the quantity of RCRA metals in the fly ash that can be incorporated into the resultant vitrified waste form. A particular concern was the heavily chlorinated fly ash. The presence of chlorine may increase the loss of RCRA metals from the slag to unacceptable levels.

- Operability tests were performed to evaluate slag/metal separation and longer-term operations.

- Potentially difficult to treat waste stream testing. The success criterion for these tests was the performance of the waste form based on TCLP results.

- Refractory performance testing was conducted under both basic and acidic conditions.

- Metals partitioning was evaluated during testing.

<u>Radioactive Bench-Scale Testing</u>
Demonstration of the PHP technology next moved on to RBS and NPS testing. These activities were to run concurrently to support similitude tests between the two systems. Because of schedule conflicts, permitting issues, and changes to workscope, the similitude testing was not completed as planned.

Tests using feeds containing hazardous materials and radionuclide surrogates were initiated in the RBS system (Carney and Felicione 1998). A summary of these tests is listed in Table 4. The key issues to be addressed through the RBS test program included:

- Metals partitioning to the offgas system. Samples were taken during each of the tests for metals analysis.

- Degree of correlation between radionuclides and their surrogates. For example, these tests would have included a comparison of data collected from runs using plutonium and runs using a cerium surrogate. These tests were not conducted because an end user could not be identified.

- Utility of using RBS correlation and RBS/NPS similitude studies to support system scale-up. With these data, the number of large-scale tests required to demonstrate the technology is minimized (cost savings).

- Ability to treat difficult waste streams. The “difficult to treat waste streams” that were tested included heterogeneous debris with chunks of graphite, wood, and fire brick. The success criterion for these tests was the performance of the waste form based on TCLP results.

- Operability/maintainability of the system.

Table 3. Treatability testing in the Nonradioactive Bench-Scale System (NBS) Plasma Hearth Process (PHP) system

Test#	Test Objectives	Feed Composition	Results
1	• Processability of dry scrubber flyash • Quantity of RCRA metals incorporated into waste form	NBS fly ash	Waste processed easily, forming a uniform molten pool. Slag passed TCLP. Metals partitioning to the slag was: Ce – 770%, Cr – 845%, Ni – 9%, Se – 4%, and Pb – 1%. Hg was below the detection limits for the slag analysis.
2	• Processability of baghouse flyash • Quantity of RCRA metals incorporated into waste form	Proof of principle fly ash	Waste processed easily, forming a uniform molten pool. Slag passed TCLP. Metals partitioning to the slag was: Ce – 50%, Cr – 380%, Ni – 6%, Pb – 0.1%, and Cs – 4100%. Cd was below the detection limits for the slag analysis.
3	• Hearth temperature vs. liquidity of metals through weir • Evaluation of water-cooled feed block	INEEL soil, steel	System too cold for metal pouring.
5	• Same as for above test but with different ground path	INEEL soil, steel	System too cold for metal pouring.
4/6	• Longer-term operability of K-3 crucible • Hearth temperature vs. liquidity of metals through underflow weir with altered ground path	Organic sludge, inorganic sludge, and combustible debris	
7/8	• Long-term operability with basic slag • Water-cooled feed block and shroud spool evaluation • APCS heat loss evaluation • Metals partitioning evaluation	RBS inorganic sludge (including metals)	System operated for 10 hours. Slag passed TCLP. Metals partitioning to the slag was: Ce – 150%, Cr – 450%, Ni – 1%, Ba – 125%, and Be – 35%. Pb, Cs, and Cd were below the detection limits for the slag analysis.
9	• Processability of high volume debris • Assessment of NO_x generation	Concrete, asphalt, sheet rock, firebrick, sodium nitrate	The first four materials processed easily, although the firebrick could not be processed without an existing molten pool in which to melt the material. During the processing of the sodium nitrate, no plume was observed at the stack, but NO_x emissions jumped from 20 (baseline) to 450 ppm and dropped back to 20 ppm in less than 20 minutes.

Table 3. (continued).

Test#	Test Objectives	Feed Composition	Results
10/11	• Long-term operability with acidic slag • Water-cooled feed block and shroud spool evaluation • APCS heat loss evaluation • Metals partitioning evaluation	RBS organic sludge (including metals)	System operated for 20 hours. All systems performed well except for metal pouring. Slag passed TCLP. Metals partitioning to the slag was: Ce – 300%, Ni – 5%, Ba – 5%, and Be – 5%. Pb and Cs were below the detection limits for the slag analysis.
12	• Behavior and fate of lead and zinc	INEEL soil	Passed TCLP for everything but lead. Failure may have been due to metallic lead inclusions in the slag resulting from insufficient operating time for oxidization. Metals partitioning to the slag was: Pb – 9% and Zn – 4%.
13	• Processability of a nitrate sludge • Assessment of NO_x generation • Metals partitioning evaluation	Nitrate sludge (including criteria metals)	Passed TCLP. Established a baseline oxygen content for comparison with Test 15. Metals partitioning to the slag was: Ce – 92%, Cr – 750%, and Pb – 10%.
14	• Processability of sulfate/nitrate sludge • Assessment of NO_x and SO_x generation • Metals partitioning evaluation	Sulfate/nitrate sludge (including criteria metals)	Passed TCLP. Metals partitioning to the slag was: Ce – 60%, Cr – 1795%, Ni – 10%, Pb – 4%, Cs – 2%, Be – 53%, and S – 2%.
15	• Processability of scrubber salt • Fate of metals and chlorine evaluation	POP fly ash/ simulated blowdown salt, high chlorine content	Waste processed easily, forming a uniform molten pool, slag passed TCLP. Much reduced NO_x emission peaks when compared to Test 13. Metals partitioning to the slag was: Ce – 30%, Cr – 348%, Ni – 64%, Pb – 5%, and Cd – 0.3%. Cs was below the detection limits for the slag analysis.
16	• Assessment of the durability of alternative refractory at the crucible hot face with a basic slag	RBS organic sludge (w/out metals)	The baseline refractory was an alumina-chrome material (Harbison-Walker [H-W] Ruby). The new refractories tested included: zircon (zirconium silicate), high alumina (H-W Korundal), MgO (H-W Harklase), and a high chromia-alumina fused cast material (Carborundum's K-3). Several differences were noted in refractory performance. The K-3 performed best followed by (in decreasing order) Ruby, Harklase, Korundal, and Zircon. The zirconium silicate material was almost completely consumed by the test.

Table 3. (continued).

Test#	Test Objectives	Feed Composition	Results
17	• Assessment of the durability of alternative refractory at the crucible hot face with an acidic slag	RBS organic sludge (w/out metals)	The baseline refractory was an alumina-chrome material (Harbison-Walker [H-W] Ruby). The new refractories tested included: zircon (zirconium silicate), high alumina (H-W Korundal), MgO (H-W Harklase), and a high chromia-alumina fused cast material (Carborundum's K-3). No large observable differences between the performance of the Ruby and any of the other materials.
18	• Determine the efficacy of a K-3 dam/weir for slag/metal separation	INEEL soil and steel	
19	• Processability of a nitrate sludge • Sensitivity of NO_x on primary chamber and SC stoichiometries	Combustible debris (PPE and wood) and nitrate sludge	

Table 4. Treatability testing in the Radioactive Bench-Scale (RBS) Plasma Hearth Process (PHP) system

Ops #	Test Objectives	Feed Composition	Results/Comments
1, 2	• System checkout	Inorganic sludge	The metal mass of the primer material (34.3 kg) in the system was compared to that added (10 kg) and it was found that in an oxidizing atmosphere the final mass of metal is reduced (21.4 kg).
3, 4	• First test with surrogate waste • Evaluate metals partitioning • Evaluate waste form performance (TCLP).	Inorganic sludge	The metal mass of the primer material (33.2 kg) in the system was compared to that added (10 kg) and it was found that in an oxidizing atmosphere the final mass of metal is reduced (24.3 kg). Cerium partitioned primarily to the slag. Cesium chloride was added to the feed, but accurate partitioning could not be determined. It appears that the majority of cesium is either entrained or volatilized to the offgas. The slag passed TCLP for all analytes, however the quantities of chromium, nickel, and cadmium were close to the UTS limits. Note these three elements were not present in the feed, but were eroded from the hearth refractory.
5, 6, 7	• Same waste recipe as above, but with hazardous materials added • Evaluate homogeneity of molten pool • Evaluate offgas emissions • Evaluate metals partitioning	Inorganic sludge with hazardous materials spikes	The homogeneity of the molten pool (four quadrants) was evaluated using the cerium concentrations in each quadrant. It was concluded that the slag was not sufficiently homogeneous to characterize the entire pool by sampling only one quadrant, but one sample from each quadrant could be used to estimate the pool composition. Particulate emissions were 0.00056 gr/dscf @7% O_2 or 0.000060 g particulate emitted/g dry feed. Cerium partitioned primarily to the slag. Cesium chloride was added to the feed but accurate partitioning could not be determined. It appears that the majority of cesium is either entrained or volatilized to the offgas. Mercury, cadmium, and lead were partitioned predominantly to the offgas system.
8	• Determine ability to process problem materials • Evaluate offgas emissions • Evaluate metals partitioning	Heterogeneous debris with chunks of graphite, wood, and fire brick	Particulate emissions were 0.0012 gr/dscf @7% O_2 or 0.00013 g particulate emitted/g dry feed. The metal mass of the primer material (34.3 kg) in the system was compared to that added (10 kg) and it was found that in a reducing atmosphere the final mass of metal did not change (44 kg). Cerium partitioned primarily partitioned to the slag. Cesium chloride was added to the feed but accurate partitioning could not be determined. It appears that the majority of cesium is either entrained or volatilized to the offgas.

Table 4. (continued).

Ops #	Test Objectives	Feed Composition	Results/Comments
9	• Combustion study	Combustible debris	Particulate emissions were 0.0025 gr/dscf @7% O_2 or 0.00043 g particulate emitted/g dry feed. The metal mass of the primer material (32.2 kg) in the system was compared to that added (10 kg) and it was found that in a reducing atmosphere the final mass of metal did not change (44 kg). Only approximately 60% of the cerium partitioned to the slag. The remainder appeared to be split between the metal and offgas components. Cesium chloride was added to the feed but accurate partitioning could not be determined. It appears that the majority of cesium is either entrained or volatilized.
10, 11, 12, 13	• Evaluate metals partitioning	High-silica sludge, high silica primer materials Basic sludge	Cerium and barium recovery in the slag was basically 100%. 16% of the cesium was retained in the slag.
14	• Evaluate metals partitioning	High organic sludge	Cerium and barium recovery in the slag was basically 100%.
15	• Evaluate metals partitioning in a reducing atmosphere	High calcium carbonate sludge	Cerium and barium recovery in the slag was basically 100%. 100% of the cesium was volatilized.
16, 17	• Evaluate metals partitioning in an oxidizing atmosphere	High calcium carbonate sludge	Cerium and barium recovery in the slag was basically 100%. 100% of the cesium was volatilized.
18, 19	• Evaluate metals partitioning in oxidizing conditions	High organic sludge – graded organic loading of cans	Cerium and barium recovery in the slag was basically 100%. 40 – 50% of the cesium in these waste feeds was retained in the slag.
20	• Evaluate metals partitioning under oxidizing conditions • Evaluate new hearth configuration and Corundal refractory	High silica sludge	Cerium and barium recovery in the slag was basically 100%. 15% of the cesium was retained in the slag.

Nonradioactive Pilot-Scale Testing

Testing in the NPS system included a Limited Source Test, a series of three system integration tests, and three extended run-time tests.

1. A Limited Source Test was required by the State of California before initiation of experimental testing in the NPS system. Airborne emissions of HCl, particulate, selected metals, carbon monoxide, and nitrogen dioxide had to be determined. A DOE debris waste recipe was chosen as the feed material because it represents a realistic waste stream and contains 5% PVC, which provided a chlorine source for testing the packed bed scrubber in the APCS. These data provided a good baseline for emissions characterization since no hazardous material spikes were made in this waste stream. Table 5 gives a summary of the data collected during the Limited Source Test on the NPS (SAIC 1997).

2. Integrated testing was a series of tests performed to establish system process control. The objective of these tests was to demonstrate that all pilot plant process and support systems performed properly when operated collectively at design conditions. Secondary test objectives focused on evaluating the performance of process control loops used to control evaporative cooler offgas exit temperature, combustion air addition, and system vacuum pressure. Table 6 summarizes these tests.

3. Long duration tests were completed to evaluate system performance. The purpose for these tests was to gain data on operating and maintenance requirements, operational costs, emissions levels, and waste form performance. Table 6 summarizes these tests.

Table 5. Limited Source Test results from the Nonradioactive Pilot-Scale (NPS)

Requirement	PHP NPS Emission	Regulatory Limit
HCl	0.0015 lb/h (99.98% removal)	< 1.6 lb/h
Particulate	0.001 – 0.01 lb/h	0.18 lb/h
Metals, lb/h		
Antimony	<6.01E-5	
Arsenic	<2E-6	
Barium	2.7E-5 – 3.98E-5	
Beryllium	<2E-6	
[a]Cadmium	<5.01E-6	<1.6E-4
[a]Chromium	9.57E-6 – 3.45E-5	<4.4E-4
Cobalt	<1E-5	
Copper	<2.31E-5	
[a]Lead	5.42E-6 – 7.02E-6	<3.3E-4
Manganese	1.56E-5 – 3.81E-5	
[a]Nickel	8.61E-6 – 3.67E-5	<1.4E-3
Phosphorus	<5.01E-4	
Selenium	<5.01E-6	
Silver	<1E-5	
Thallium	<1E-6	
Zinc	1.04E-4 – 1.8E-4	
CO	0.0062 – 0.08 lb/h	0.6 lb/h
NO_2	0.18 – 0.46 lb/h	<4.3 lb/h
NO_x	2.0 – 3.7 lb/h	18.4 lb/h

a. Analytes of primary interest.

Table 6. Nonradioactive Pilot-Scale (NPS) Integrated System testing results

Test #	Objective	Feed Composition	Comments/Results
1, 2	• Integrated System Testing	Soil, wood, and metal	Problems identified with feed system. Modifications were made to the feeder system hardware and control logic to prevent reoccurrence. Final pour not completed due to slag buildup and overflow in the pour spout area.
3	• Duration Testing – 100 hours. • Evaluation of torch life, refractory life, and throughput.	56 drums: Soil Soil/Metal Soil/Metal/Wood Debris Empty	Test duration was 101 hours with a torch availability of approximately 84%. Torch ran for the 101 hours with one electrode change. The average processing time was 47 minutes per drum and the average feed rate was 565 lb/h. Refractory corrosion was noted around the feed and pour areas and could be attributed to the torch flame. During operations, problems were noted in the feed and pour systems. Modifications were made to these systems once testing was completed.
4	• Duration Testing – 100 hours. • Demonstrate system durability and implement lessons learned from previous duration test.	112 drums: Soil, wood, glass, concrete, and carbon steel (from drums) Empty	All drums processed. Test duration 102 hours with a torch availability of 83%. During the 102 hours of torch operation, two torch ram water leaks occurred from side arcing from the ram to the feed drum and the ram contacting the feed drums. Both problems were related to inexperienced operators. The electrode was replaced during each torch rebuild. The average processing time was 38 minutes per drum and the average feed rate was 386 lb/h. A new hearth was constructed for this test using the PHP standard hearth design and cut refractory brick. The modified pour spouts were an improvement over the first test. The refractory corrosion in the feed and pour areas was again significant due to the tail flame of the torch.
5	• Duration Testing – 150 hours. • Optimize torch operation and durability. • Maximize waste throughput. • Obtain data on refractory life.	59 drums: Soil, wood, glass, concrete, and carbon steel (from drums) Empty	The Pacific Gas and Electric (PG&E) power company ended testing early. Test duration was 52.8 hours. The average processing time was 26 minutes per drum with an average feed rate of 567 lb/h.

PHP Testing Summary

The following overall observations, conclusions, and recommendations resulted from the NBS, RBS, and NPS testing.

NBS

- Testing was completed to evaluate an underflow weir to separate metal from slag in the melter (NBS Tests 3, 4/6, 5, and 18. During Tests 3 and 5, metal did not flow in the metal crucible until torch placed directly overhead, which destroyed the refractory dam. Based on these tests, the crucible was redesigned to feature a covered metal crucible to solve the problem of metals leaking out of the slag crucible between refractory pieces. Test 4/6 was run to evaluate the redesign and was successfully completed. Test 18 determined that the NBS system is still too cold for metal pouring, but more metal flowed into the metal crucible than during previous tests.

- The PHP can process its own fly ash.

- Total mass feed partitioning test results showed that the elements can be divided into broad groups: high affinity for slag (Ce, Cr), intermediate affinity for slag (Be, Ba), and low affinity for slag (Pb, Ni, Se, Hg, S, Cs, Cd). The data also showed that the design of the NBS APCS did not allow for accurate mass balance closure from test to test.

- Partitioning data and mass balance closure was difficult to obtain in the NBS system. Based on the NBS experience, the RBS and NPS systems were designed to obtain mass balance closure on materials. Iron, cerium, barium, and cesium were the elements selected to evaluate material recovery values in the RBS system. Recovery data for iron and cerium were 100% $\pm$ 10%. 80 – 90% of the barium was retained in the slag and 0 – 50% of the cesium was retained in the slag.

RBS

- Samples of the final waste form consistently passed TCLP except for waste with high quantities of metallic zinc. Large quantities of metallic zinc may pose problems for the PHP in terms of maintaining process control. Further examination of metallic zinc is recommended to establish Waste Acceptance Criteria for zinc.

- Operational problems surfaced during several of the tests.

  — During initial tests, torch operational problems occurred. The torch was disassembled, but no problems found. Another experiment was aborted when the torch was grounded by a software position error and the internals were damaged. The experiment was completed, but a badly oxidized torch thermal shield was discovered during postrun equipment inspection.

  — Operation 10 was aborted because of high, unsteady pressure losses in offgas – system was inspected but nothing found. The experiment was reinitiated but the arc failed – inspection revealed melt-through of hearth at strike-off pad. After maintenance the experiment was restarted and completed.

- Cerium oxide (plutonium oxide surrogate) was found to primarily partition to the vitreous slag. Slightly higher retention rates were noted for sludges as compared to combustible debris wastes.

- All high vapor pressure hazardous metals (Hg, Cd, and Pb), except barium, partitioned to the offgas system, where they were removed before release out the stack.

- Homogeneity of the molten pool in the RBS system was poor for several of the tests. This was partially attributed to high melt viscosities.

- Deliberate and inadvertent water leaks in the process show that the system appears to be safe to steam explosion, with no release of hazardous contaminants to the environment.

- Dispersion of cesium throughout the system was noted. High calcium wastes created slags that exhibited the poorest retention of cesium.

- Except for mercury, stack emissions of metals, diatomic chlorine, and HCl were either near or below limits of detectability.

NPS

- 24-hour continuous operation is attainable in the NPS system. The NPS system completed two, 100-hour runs.

- Product pouring in the NPS system was successfully accomplished (approximately 40,000 lb of surrogate waste processed). The separation of metals from slag was unsuccessful in the NPS system, due to temperature of materials near bottom of crucible. The system may be modified to accomplish this task for future SAIC testing.

- Testing in the developmental systems has identified several equipment and operations problems. The modifications made to hardware and procedures through operating experience have shown improved reliability and reduced maintenance in the NPS system.

- The PG&E power company ended testing early. Test duration was 52.8 hours. Improvements were made to the torch before this test to allow operations at higher power output and longer arc lengths. However, voltage fluctuations were detected on the power grid whenever the torch was started or stopped during testing. PG&E was unable to isolate the residential customers from the voltage spikes created by the torch within a timeframe that would allow the test to continue.

- The NPS offgas system controlled emissions to below EPA requirements.

- Slag samples passed the EPA's TCLP with a comfortable margin. This margin was reduced, particularly for Cr, Cd, and Pb, when compared to the proposed UTSs.

- Total particulate stack emissions were one-to-two orders of magnitude below EPA allowables, despite evidence of dry particulate carryover from the acid-scrubber.

Key System Parameters

Waste Acceptance Criteria for a PHP type treatment process will include physical, chemical, and radiological constraints based on regulatory and process capability considerations. The PHP is a fairly robust process that minimizes the physical constraints of the waste feed. Physical problems are related primarily to industrial safety problems, such as volatile liquid or steam pressure excursions. Chemical and radiological constraints are primarily related to regulatory emissions requirements and operations personnel exposures, respectively. Based on experimental data collected from the NBS, RBS, and NPS tests, SAIC prepared a conceptual design report for a production waste treatment facility (Gillins, Hendrickson, and Wilson 1998). The document presents a set of Waste Acceptance Criteria for the operating treatment facility, including several assumptions. The Waste Acceptance Criteria for the theoretical treatment facility can be summarized as follows:

- Radiation Field – Limited to contact-handled wastes (⊆200 mrem/h).

- Alpha Activity – Will be determined from facility design.

- External Radiological Contamination – Will be determined from facility design.

- Weight Limitations – Determined from material handling equipment selected for facility design and Department of Transportation (DOT) limitations for 55-gallon waste drums.

- Regulatory Requirements – Requirements are driven by state regulators and are established for each facility in its operating permit. These generally relate to excluded or quantity-limited materials such as mercury, lead, or chlorine.

- Free Liquids – No containerized free liquids; unconfined free liquids limited to 5% by volume (although may vary by waste stream).

- Pressurized Containers – No pressurized containers accepted.

Limitations/Potential Problems

The original assumption for using a high-temperature melter to treat waste was that a minimum amount of waste characterization would be needed before processing. The melter system would be capable of taking nearly any type waste, destroying any organics, and producing a homogeneous waste form. The waste form would then be characterized before disposal. Testing has demonstrated a need for more characterization than originally anticipated. There are several reasons why characterization is needed: to ensure refractory lining stability, to maintain the melt viscosity, and to satisfy regulatory concerns about releases to the environment. Refractory lining is selected based on the type of waste that is processed. Feed that is highly oxidizing will require a refractory that is quite different from one chosen for a highly reducing feed. Refractory corrosion can affect the melt viscosity and waste form quality. High refractory corrosion rates will affect the maintenance schedule and could create safety and health concerns, such as the potential for a leak to the environment, offgas excursions, and worker contamination.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

This section addresses in more detail the types of mixed waste streams that the PHP is most amenable to and also compares the PHP technology to other competing high-temperature melter technologies and defines the status, commercial availability, and maturity of the PHP technology.

Competing Technologies

A second plasma-heated melter technology, funded through the MWFA, was the Graphite Electrode Direct Current (DC) Arc system. The DC graphite arc melter system has been developed by Pacific Northwest National Laboratory (PNNL). PNNL has three, DC arc, graphite electrode based melters: NBS melter, RBS melter; and radioactive engineering-scale pilot melter.

The PNNL bench-scale radioactive melter is installed in a laboratory hood rated for radioactive service. The system is composed of a fixed graphite cylindrical hearth that is 4.25 inches high and 4.25 inches wide with a single top-centering graphite electrode. The melter operates at between 1,371 – 1,482^{o}C with batch sizes between 1.7 – 2.2 pounds of dry feed. A screw auger is used to feed materials into the system. The NBS melter is of the same design, but it is located in a nonradioactive work area. The NBS system allows scoping tests to be done quickly and inexpensively.

The PNNL radioactive engineering-scale system is a cylindrical 3-foot by 4-foot primary vessel with a 12 inch diameter fixed graphite hearth. The engineering-scale unit can process up to 100 pounds per hour with an energy input of up to 250 kW and is equipped with a large object feeder and a screw auger.

In addition to the PNNL melters, the Savannah River Site (SRS) has a radioactive, bench-scale system that is being used exclusively to study the behavior of small particle size Pu-238 (<1 micron in diameter). The SRS effort is focused specifically on the special Pu-238 processing and handling issues of concern to SRS. The design of the SRS melter is similar to the PNNL RBS system. The objective of this work is to develop a processing option for the Pu-238 contaminated job control waste inventory at SRS.

The PHP and Graphite Electrode DC Arc melter technologies both perform a basic melting function to treat mixed waste. The primary difference between the systems is the manner in which the heat is applied to the waste, which results in advantages and disadvantages for each technology. The DC Arc melter has a solid graphite electrode in the center of the melter. This electrode arcs to a second electrode under the molten pool. Since arc melters typically use graphite electrodes, their redox flexibility is somewhat limited. Therefore, the melters tend to operate in more reducing than oxidizing conditions.

The PHP melter uses a plasma generated as an arc between two electrodes, similar to the Graphite Electrode DC Arc melter. However, in the PHP, the arc is pushed out or stretched from the electrode via gas pressure. The second electrode is generally under the molten pool (as in the arc melter). The gases used to push out the arc can also be varied to adjust the redox state of the melter chamber from reducing to oxidizing. This stretched arc can range from 15 to 75 cm in length. The long length of the arc increases the volatility of some waste components in the feed, which must be collected in the offgas system.

Technology Applicability

The MWFA funded the development and demonstration of high-temperature melter technologies as an option for hazardous and radioactive waste treatment. The PHP was one of two technologies selected by the MWFA (out of a field of approximately 13 technologies) as potentially applicable to treatment of mixed wastes (both transuranic and nontransuranic). The selection process reviewed available technologies against their potential abilities to address the highest risk problems, largest volumes of wastes, and stage of development. A technical peer review was held in FY-96 to aid the DOE in making this decision. Unique to this review was the fact that both an internal users and stakeholders panel and an external experts panel were used to evaluate the technology presentations.

The MWFA then worked with potential end users in deriving the needed test requirements and objectives, and directing specific test objectives to the appropriate PHP melter system. The original target wastes for the PHP process were the stored mixed wastes at the INEEL's RWMC. These stored wastes are comprised of a wide range of materials generated throughout the nuclear defense complex. They include both aqueous and organic sludges, dirt and construction debris, and other miscellaneous materials. These wastes have been accumulated since 1970, having come predominantly from weapons-production operations at the DOE's Rocky Flats Plant. These wastes will now be treated under a privatization effort called the Advanced Mixed Waste Treatment Project (AMWTP).

Technology Status and Maturity

The PHP has progressed from batch, bench-scale experiments at the STAR Center through semibatch, bench-scale experiments at ANL-W, to continuous, pilot-scale testing in Ukiah, California on a full-scale system. Surrogate INEEL waste streams were tested in each of these systems. Hazardous materials and radionuclide surrogates were used in both bench-scale system demonstrations. Only a nonhazardous, nonradioactive waste treatment demonstration was completed in the pilot-scale system. To satisfy regulatory and stakeholder concerns it is anticipated that real waste demonstrations will need to be completed before system implementation at any site. The real waste demonstration will require bench-scale testing, both surrogate and real waste, and then at a minimum, large-scale testing of a surrogate waste for comparison.

Patents/Commercialization/Sponsor

The PHP technology is owned by SAIC. SAIC has brought in British Nuclear Fuels, Limited (BNFL) to complete a technical evaluation of the technology to determine its potential marketability. This evaluation will be completed in FY-98. SAIC can be contacted for detailed information on the PHP technology.

SECTION 5

COST

Methodology

The cost estimates summarized in this section are at the planning estimate level. These cost estimates are based on the report *Process System Inputs for a Conceptual Design Report: PHP Production Waste Treatment Facility*, SAIC-98/2701, March 1998 (Gillins, Hendrickson, and Wilson 1998) and the facility costs identified in the letter "Title 3 Construction Cost Estimate for the Waste Characterization Facility," INEL letter, SMB104-94, November 22, 1994 (Bradford 1994). The cost and contingency application methods used in this section follow the Good Practice Guide on Life-Cycle Cost and multiple Cost Estimating Guides.

Assumptions used in cost estimate:

- New facility will be constructed to house process equipment
- New process equipment will be purchased
- 1 year for design and permitting of facility
- 2 years for construction and startup of facility
- Facility would process 17,000 cubic meters of waste over 5 years of operation
- Facility would process 2,400 cubic meters in first year, and 3,600 cubic meters in years 2 through 5
- Facility throughput rate is 1.6 drums per hour (about 0.2 cubic meters per drum average) for first year, and 2.5 drums per hour for years 2 through 5 (during testing, rates of 1.7 to 2.0 drums per hour were achieved)
- Drum equivalent is estimated at 300 pounds per drum
- 1 year for decontamination and decommissioning of facility.

The referenced report then addressed collecting data for estimating these costs:

- Cost to purchase furnace system, offgas system, and secondary combustion chamber
- Cost to design facility
- Cost to prepare site
- Cost to construct and outfit facility
- Cost to permit facility
- Cost to operate facility (labor cost, utilities cost)
- Cost to maintain facility (equipment replacement cost, consumables cost)
- Cost to dispose of secondary waste
- Cost to dispose of primary waste product.

Some of the cost data were based on the testing during the development and demonstration phases; other cost data were based on past melter installations.

Cost Analysis

Capital costs are estimated at $50,000,000 to $86,200,000 for the production facility construction and outfitting. Operations budget funded activities are estimated at $12,000,000 to $18,000,000 through the startup period. Operations and maintenance costs are estimated at $48,000,000 to $62,000,000 for a 5-year operating period. Decontamination and decommissioning costs are estimated at $4,000,000 to $8,000,000 for a 1-year decommissioning period. Product disposal costs are estimated at $10,000,000. The total life cycle costs are estimated at $124,000,000 to $184,000,000.

Conclusions

End users should examine the assumptions used in this analysis before applying the cost estimates to their site-specific solution. Using the PHP to treat about 17,000 cubic meters, the treatment and disposal costs are projected at $7,400 to $10,800 per cubic meters.

SECTION 6

REGULATORY AND POLICY ISSUES

This section presents current and anticipated regulatory requirements that an end user of a high-temperature melter technology would have to meet before mixed waste treatment and during any development phases. The specific regulatory requirements and their associated issues that pertained to the PHP effort are also described.

This section also presents an analysis performed by the MWFA that assesses the various risks involved with deployment of the PHP and pertinent stakeholder responses to the siting of a mixed waste thermal treatment facility in a given community.

Regulatory Considerations

The objective of using PHP to treat mixed waste was to produce waste forms that could meet applicable Land Disposal Restriction (LDR) treatment standards for organics and metals. Small amounts of metals/radionuclides are expected to volatilize to the offgas or be entrained in the offgas during processing of wastes. A highly efficient, state-of-the-art APCS is required to remove particulate, acid gases, and any volatilized toxic metals or radionuclides. The APCS planned for the PHP technology included an evaporative cooler, a baghouse, HEPA filters, and a full quench/packed-bed scrubber. Feed control was also to be used to assist in controlling potential emissions. Additional controls for mercury emissions may be needed, depending on the mercury content of the feed.

Major regulatory requirements, including permit/license requirements, for implementation of this technology to treat RCRA LDR mixed wastes are expected to include:

- National Environmental Policy Act (NEPA) review for implementation at federal facilities (categorical exclusion is likely to apply for treatability studies). At DOE facilities, this includes an initial environmental checklist that is used to assist in determining if a more detailed environmental assessment or environmental impact statement is required.
- A radioactive material license from the Nuclear Regulatory Commission (NRC) or its applicable agreement state for non-DOE facilities or for DOE facilities expected to be regulated by NRC or the agreement state.
- RCRA notifications or applications submitted to the regulatory agency based upon the scale and purpose of the process and the capability of the process to achieve the required treatment of LDR wastes and meet applicable LDR treatment standards.
  - — Notification to applicable regulatory agency (state or EPA) for treatability studies.
  - — Variance or Determination of Equivalent Treatment to allow disposal of treated wastes and residues if the waste is subject to a specific technology based LDR treatment standard (such as incineration).
  - — Waste Analysis and Treatment Plans for wastes treated by generator under 40 CFR 262.34 or under 40 CFR 254 or 265 for wastes to be treated at permitted facilities.
  - — Submittal of a permit application or modification to applicable regulatory agency (state or EPA) for review and approval of treatments that are not treatability studies. Currently, risk assessment for emissions and effluents is required for this.
- Clean Air Act (CAA) permitting
  - — National Environmental Standards for Hazardous Air Pollutants (NESHAPS) applicability review to determine the need for NESHAPS permitting or air/emissions monitoring for any operation that involves potential releases of particulates, gases, or vapors that may contain radionuclides or other regulated hazardous air pollutants. The forthcoming (ca. January 1999) Maximum

Achievable Control Technology (MACT) based NESHAPs, (including standards for dioxin, mercury, other toxic metals, particulate matter, CO, hydrocarbons, and HCl) and the associated requirements for continuous emissions monitoring of particulate emissions, may also be applied by state regulatory agencies to thermal mixed waste treatment technologies via the RCRA permitting “omnibus" provision.

— National Ambient Air Quality Standards (NAAQS) and New Source Performance Standards (NSPS) applicability evaluation and Prevention of Significant Deterioration (PSD) review to determine the need for Permit to Construct (PTC) application or air permit modification as applicable.

— Liquid effluent/wastewater (such as scrubber blowdown) treatment needed to meet National Pollutant Discharge Elimination System (NPDES), publicly owned treatment work (POTW), or other applicable wastewater disposal requirements.

— Treatment and disposal requirements for other secondary waste streams, e.g.,
  Spent pre-HEPA and HEPA filters from offgas system
  Spent baghouse filters
  Spent refractory
  Excess fly ash
  Dry blowdown salts
  Miscellaneous maintenance, repair, and operations wastes.

- State- or locality-specific requirements, e.g., siting, zoning, historic preservation, and other laws and regulations, that may require additional permits and licenses.

- Treatment of hazardous waste or mixed waste must meet the applicable RCRA 40 CFR 268.40 LDR treatment standards for wastewaters or nonwastewaters and including treatment of underlying hazardous constituents to UTSs, as applicable. NRC waste form testing requirements may also need to be met for disposal in NRC licensed sites. Individual commercial and DOE disposal sites may have site-specific requirements, including specific radionuclide limitations that may affect qualification of the final waste form.

- The regulatory activities conducted for the PHP systems tested include [(SAIC 1994), (SAIC 1995), (Green 1996), (SAIC 1997)]:

— The PTC application for the RBS system was submitted to the State of Idaho on April 30, 1994. A PTC No. 011-00022 and modification to this PTC were issued by the Idaho Department of Environmental Quality on February 2, 1996, and May 6, 1996, respectively. The modification was for replacement of a baghouse dust collection system with an industrial grade HEPA filter. The total material feed rate to the plasma chamber was limited to 30 lb/h and 15,600 lb/h and the feed rates of mercury and beryllium were limited to 400.4 lb/qtr (1,601.6 lb/yr) and 1,999 lb/qtr (7,997.6 lb/yr), respectively. Yearly hours of operation were limited to 520. The minimum outlet temperature of the Secondary Combustion Chamber was 982^{o}C and the temperature at the particulate control device was limited to 260^{o}C. Prevention of Significant Deterioration (PSD) review performed by the state determined that the project did not involve PSD PTC requirements.

— A NESHAPs request for approval to construct the RBS system was submitted to EPA, Region X, on April 30, 1994, and approved by letter dated May 10, 1994. Under 40 CFR 61.93, periodic flow measurements were necessary and continuous radionuclide sampling was required during operation.

— An environmental checklist for the RBS treatability study was submitted February 15, 1994. It was determined, in a letter dated September 1, 1994, that the project met the requirements of a categorical exclusion under NEPA Regulation, 10 CFR Part 1021.400, Subpart D, Section B3.10.

— On January 31, 1997, and October 20, 1997, Authority to Construct permits were issued by the County of Mendocino (State of California) Air Quality Management District (Permit Number 2080-3-14-94-19-6 and Permit Number 2080-3-14-97-54-6) for 1-year periods for the NPS system at RETECH, Ukiah, California. Opacity, CO, Ox, SO2, PM, PM-10, and total organics emissions

were limited, as well as Cd, Cr, HCl, Pb, and Ni emissions. The maximum feed rate was limited to 1,500 lb/h in the first and second permits. The average feed rate was limited to 400 lb/h in the first permit. A second maximum feed rate of 36,000 lb/in. any 24-hour period was imposed by the second permit.

— 45-day notifications of the RCRA Treatability Study were submitted to the applicable regulatory agencies. As part of the 45-day notice of the bench-scale treatability study, the State of Idaho required an additional description of the project, submitted on September 9, 1994.

To provide necessary information for permitting and determining monitoring requirements, the PHP material and energy balance model was used to estimate the relative quantities of materials in the exit streams. The PHP is discussed in the Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration Waste Management Programs Final Environmental Impact Statement, April 1995 (DOE/EIS-0203-F).

Regulatory Issues

This demonstration stage project experienced no unusual regulatory issues. The issuance of the PTC for the bench-scale PHP unit required resolution of a Notice of Deficiency (NOD) addressing the potential for release of gaseous radionuclides. Although the relatively high temperatures and nature of the process can be expected to volatilize and entrain small amounts of chemical species into the offgas, low PHP gas flow rate combined with a state-of-the-art APCS could be expected to minimize issues associated with air emissions. Proof-of-principle tests using nonradioactive cesium indicated that at least 99.95% of the cesium was in particulate form that could be captured by a baghouse. There is still the potential however, that associated air emissions control issues could vary significantly depending on the states and individual regulators involved in approval of a PHP unit.

The ability of the bench-scale final PHP waste form to pass TCLP would need to be verified for larger PHP units and different feeds. The ability of the final waste form to meet all applicable LDR Treatment Standards in 40 CFR 260.40, including applicable UTSs (40 CFR 260.40) for Underlying Hazardous Constituents would also need to be verified.

Safety, Risks, Benefits, and Community Reaction

Eight risk areas were evaluated and assessed independently. These risk values for MWFA developed technologies have been derived from the eight top level requirements defined in the MWFA Systems Requirements Document (INEL 1997). The eight areas evaluated for level of risk are (1) ease of permitting, (2) technical correctness, (3) level of safe operability, (4) technical completeness (i.e., ready to use), (5) timely to meet treatment schedules, (6) acceptability to stakeholders, (7) cost-effectiveness to use, and (8) committed sponsorship. A complete description of the methodology and a detailed definition of each risk element, the event scenario, and the basis for assigning consequences and probability factors are included in Appendix C.

The PHP was evaluated against these eight risk areas. The evaluation is based on the PHP's current stage of development and the testing completed to date. Below is a summary of the risk evaluation.

- Permittable: The risk category is rated as high. A permit to operate a plasma torch melter has never been submitted for a mixed waste treatment operation. Several R&D permits have been issued to process hazardous wastes and ANL-W obtained a PTC, RCRA Treatability Study, and a categorical exclusion under NEPA permit to complete limited testing in the RBS system. It is expected that the permitting process will be similar to that of an incinerator (similar temperatures; feed will contain organics and metals). Experience to date is that permitting for an incineration process is very difficult. Data required to begin the permitting process have been collected through the development program.

- Complete: The risk category is rated as high for heterogeneous wastes. The original concept of this technology was to treat heterogeneous sludge and debris type wastes. Additional demonstration testing would be required for the specific waste types requiring treatment in this system. Note: The risk category would be significantly lower for characterized, fairly homogeneous waste streams.

- Acceptable: The risk category for acceptable is rated as medium. There has been much experience

with the public perception of incinerator operations. The PHP APCS was designed similarly to the incinerator systems. The PHP also releases much lower volumes of offgases during treatment. It is expected that the Tribes and public will perceive that the technology is solving an important problem but that it would have a negative impact on the quality of life for those residents near the operating facility.

- Timely: This category is listed as not applicable since there is currently no end user identified within DOE Environmental Management (EM).

- Cost: The risk category is rated as high. A large volume of waste would be targeted for a PHP facility due to the construction and operations costs. These construction and operational costs are based on data collected from surrogate waste tests. A real waste demonstration has not been completed.

- Sponsored: This category is listed as medium high. Originally, this technology was developed to support treatment of the INEEL waste streams. There is surrogate data available on a number of waste types (streams), which is representative of approximately 40% of the DOE mixed waste (based on waste volume to AMWTP and total DOE mixed waste volume). Treatment of the INEEL waste was privatized through the AMWTP, which will not be using the PHP technology. There has since been no commitments made to use this technology.

- Correct: This category is listed as high. Again, this technology would only be selected by a site to treat a large quantity of waste. The selection of this technology would be a high risk due to the quantity of waste that would be affected by failure of the technology. Much surrogate testing has been completed to reduce this risk, however real waste tests have not been completed yet.

- Safe: This category is listed as medium-low. Hazardous materials will not be added to facilitate the treatment process. There is, however, a potential to generate dioxins and furans due to the presence of organics in the feed. Dioxins and furans release to the environment will be controlled through the use of a secondary combustion chamber. Since this is a highly complex and energetic system (operating temperatures are estimated at 1,149 – 1,538°C), the likelihood of a system failure was high.

The siting of a mixed waste thermal treatment facility near communities will involve public input. Stakeholders may be concerned about the type, toxicity, and amount of emissions to be discharged to the atmosphere and the final disposal site for the slag and metal waste forms. However, past communication with the stakeholder, in regards to these issues, indicate that high-temperature treatment is a favorable technology because it creates a relatively low volume of final waste, which is also highly durable.

The MWFA Tribal and Public Involvement Resource Team initiated activities to involve and gather stakeholder issues, needs, and concerns about thermal treatment technologies. In addition, the PHP project team conducted several activities to support public involvement and obtain stakeholder input on the PHP project. These activities included reviews, tours, articles, presentations, and press releases. The detailed information on these activities and documents, included as part of the Public and Tribal Involvement Record, are included in Appendix D.

The MWFA generated a "Stakeholder Comments Database," which is a compilation of public reports containing stakeholder comments. Data are grouped by keywords. The database is accessible on the MWFA homepage (http://wastenot.inel.gov). Following are general stakeholder issues and concerns regarding thermal treatment processes found in public reports and can be found in the database. For example, one specific source document that can be accessed in the database contains stakeholder comments/concerns specific to the PHP process:

- high temperature of the system,
- high complexity of the system,
- potential for accidents – explosion, cooling system failure, and process abnormalities;
- potential to impact worker safety due to operating conditions,
- air emissions - no "real time" monitoring devices, release of volatile contaminants;
- potential for incomplete combustion, dioxin/furan formation,
- destruction and removal efficiency (DRE) not a reliable basis for exposure assessment.

Stakeholders are concerned about a technology's ability to remediate all contaminants it encounters. They want technologies to take care of the entire problem. However, tradeoffs are inherent and should be communicated to stakeholders upfront.

Stakeholders require that a technology not increase the mobility of contaminants it is designed to remediate. All incinerators, and other systems that are based on combustion, have the potential to emit heavy metals and other pollutants.

Overall, in developing technologies for application by the MWFA, waste generation should be minimized, including minimizing creation of new hazardous materials through treatment and minimizing the volume of final waste forms for storage/disposal.

Lastly, the Technical Requirements Working Group (TRWG), a stakeholder group formed to assist the MWFA, reviewed and provided recommendations on changes to the Radionuclide Partitioning Technology Development Requirements Document (MWFA 1997). This document establishes the end-user performance for a technology. Their comments were reviewed and incorporated into the document.

SECTION 7

LESSONS LEARNED

Implementation Considerations

Owners of mixed waste and potential technology end users have many alternative stabilization methods to choose from including PHP, other high-temperature plasma and joule-heated melters, macroencapsulation, etc. Many factors will be considered by the end user when choosing a technology. These factors include: long-term storage and disposal costs, capital and operating costs of a treatment system, required additional development costs, ease of permitting, extent of volume reduction, ease of operation, availability of equipment, and stakeholder acceptability. At a minimum, these factors must be considered when making a technology selection.

Design Issues

Several modifications to the PHP design are recommended by the PHP Principal Investigators, based on demonstration operations. The following modifications/enhancements should be considered before implementation:

- modification and demonstration of the tilt-pour system to separate slag and metal phases,
- evaluate process operability/reliability with torch change out using latest Western Environmental Technologies Office (WETO) data on torch life extension.

Technology Limitations and Needs for Future Development

The decision to close out this developmental program in FY-97 was made for two reasons: (1) the AMWTP contract at the INEEL will not be using the PHP technology and no other end users have been identified and (2) the decontamination and decommissioning costs could not be justified for a radioactive operation with no end user identified. Funding was supplied to the programs in FY-98 to support closeout and ITSR preparation. However, there are still unknowns related to using the PHP technology in a functioning waste treatment facility. The data collected to date are available to support reinitiation of these development activities if an end user is identified within the DOE complex.

Issues that will need to be addressed, for successful deployment of a system to treat mixed wastes, include:

- The behavior of plutonium, uranium, and other actinides compared to the cerium surrogate still must be determined to support facility design and permitting and stakeholder concerns.
- The relative behavior of metals versus oxides of actual actinides needs to be established to support operational decisions (reducing versus oxidizing) and permitting needs. This pertains to both actual actinides and surrogate actinides.
- Extensive data were gathered for sludge wastes, but experience with debris waste was limited. The debris waste experiments that were conducted found noticeable differences in system behavior as compared to the processing of sludge wastes. These differences must be quantified to support system's operations decisions and permitting needs.
- Data comparisons between the bench-scale and pilot-scale systems show significant differences in the physical entrainment rates of the feed materials. At a minimum, testing with hazardous and radioactive materials or their surrogates must be completed on a scale supporting design of an operating facility.
- Complete evaluation of operations with high organic feeds.

APPENDIX A

REFERENCES

Authority to Construct Permit Number 2080-3-14-94-19-6, County of Mendocino Air Quality Management District, issued to RETECH, M4 Environmental Division, Ukiah California, January 31, 1997, for the period July 1, 1996, through June 30, 1997.

Authority to Construct Permit Number 2080-3-14-97-54-6, County of Mendocino Air Quality Management District, issued to RETECH, inc., Ukiah California, October 21, 1997, for the period October 21, 1997, through October 20, 1998.

Carney, K.P. and F.S. Felicione. February 1998. *Plasma hearth process bench-scale system testing FY-97 final report*. W0410-0185-ES-00.

Gillins, R.L., K.D. Hendrickson, and J.M. Wilson. March 1998. *Process system inputs for a conceptual design report: PHP production waste treatment facility*. SAIC-98/2701.

S.M. Bradford, November 22, 1994, Title 3 Construction Cost Estimate for the Waste Characterization Facility, INEL letter, SMB104-94.

Green, Orville D. May 6, 1996. Permits and Enforcement, Idaho Department of Health and Welfare Division of Environmental Quality Permit to Construct Amendment – Plasma Hearth Process, letter to Ernest J. Hughes, Argonne Group-West.

Idaho National Engineering and Environmental Laboratory. Mixed Waste Focus Area Program. February 1997. *Systems requirements document* (Draft). INEL/EXT-07-0159.

Leatherman, Dr. Gary L., J.D. Atkinson, Chad Cornelison, Lisa M. DeWitt, Garth R. Hassel, Kelly Rebish, and Roy Woodvine. October 1995. *Results of STAR Center testing in support of the nonradioactive pilot-scale plasma hearth process system*. SAIC-95/1313. Science Applications International Corporation. Idaho Falls, Idaho.

Mixed Waste Focus Area Program. May 1997. *Radionuclide partitioning technology development requirements document*.

SAIC Engineering Design File RFS-006, Rev. 0. September 29, 1995. The plasma hearth process treatment system: development plan and strategy for characterization and treatment compliance.

SAIC PHP-97/002. April 1997. Final PHP bench-scale report for the DOE-ID/SAIC sole source contract. Idaho Falls, Idaho.

SAIC-94/1112. Regulatory strategy for development of the plasma hearth process for the Department of Energy.

SAIC-97/2704. August 1997. Pilot-scale PHP limited source test, test report.

APPENDIX B

BIBLIOGRAPHY

Argonne National Laboratory-West. May 1997. Plasma hearth process bench-scale testing: FY97 mid-year status report. ANL-W Document No. W0410-0182-AH-00.

Barnes-Smith, P. March 1994. Life-cycle cost analysis for the plasma arc furnace. DOE/1\4WIP-25. International Technology Corporation. Albuquerque, New Mexico.

Batdorf, J.A., G.R. Hassel, and G.L. Leatherman. October 1995. Measurement of metals emissions from the plasma hearth process. 000592. Science Applications International Corporation. Idaho Falls, Idaho, for the International Symposium on Environmental Technologies in Atlanta, Georgia.

Batdorf, J.A., G.R. Hassel, W.P. Wolfe, R.M. Geimer, and J.D. Dalton. October 1995. Pilot-scale PHP demonstration test plan. SAIC-94/1115. Science Applications International Corporation. Idaho Falls, Idaho.

Batdorf, J.A., R.M. Geimer, and W.P. Wolfe. November 1992. Test results from the plasma hearth process demonstration on Rocky Flats supercompacted TRU waste. SAIC-92/1226. Science Applications International Corporation. Idaho Falls, Idaho.

Batdorf, J.A., R.M. Geimer, and W.P. Wolfe. October 1993. Test results from the plasma hearth process testing, under the buried waste integrated demonstration. SAIC-93/1071. Science Applications International Corporation. Idaho Falls, Idaho.

Batdorf, J.A., R.M. Geimer, G.R. Hassel, and W.P. Wolfe. December 1993. Test results from the plasma hearth process supplemental testing on RFP supercompacted TRU waste. SAIC-93/1072. Science Applications International Corporation. Idaho Falls, Idaho.

Bates, J.K., E.C. Buck, N.L. Dietz, D.J. Wronkiewicz, C. Whitworth, K. Filius, and D. Battleson. Printed abstract: Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management, Spectrum ’94, American Nuclear Society, pp. 2222-2229.

Carney, K.P. and F.S. Felicione. July 1995. Test plan for the plasma hearth process radioactive bench-scale system: FY97 program. ANL-W Document No. W0410-0174-AP-00.

Carney, K.P., F.S. Felicione, and C.C. Dwight. 1997. Slag Characterization results from the plasma hearth process radioactive bench-scale test program. *Proceedings of the 1997 International Conference on Incineration and Thermal Treatment Technologies.* pp. 83-88.

Carney, K.P., J.C. Demirgian, G.G. Peters, M.A. Power, and J.S. Linder. Test results: plasma hearth integrated test. draft PHP Project Internal Report.

Carney, K.P., M.A. Power, G.G. Peters, and J.S. Linder. On-line, in-situ calibration of a remotely operated, fourier transform infra-red spectrometer for the real-time monitoring of products of combustion in a radioactive offgas stream, to be submitted for publication to Applied Spectroscopy.

Carney, K.P., M.A. Power, J.C. Demirgian, J.S. Linder, P.R. Jang, and J.C. Luthe. Characterization of the combustion components for the plasma hearth mixed-waste remediation pilot-scale facility, to be submitted for publication to *Journal of Combustion Science and Technology*.

Carney, K.P., M.A. Power, J.C. Demirgian, J.S. Linder, P.R. Jang, and J.C. Luthe. Characterization of the combustion components for the plasma hearth mixed-waste remediation pilot-scale facility. draft, to be submitted for publication to *Journal of Combustion Science and Technology*.

Carney, K.P., R. DeFelici, and M.A. Smith. The measurement of Cs, Ba, and Zr by X-ray fluorescence spectrometry using Ce as a internal standard, to be submitted for publication to *X-ray Spectrometry*.

Carney, K.P, M.L. Adamic, R.E. DeFelici, T.A. Miller, R.W. Bratt, and D. Nishimoto. Analytical results and data analysis: integrated test No. 2 (T-IS-2). draft PHP Project Internal Report.

Cornelison, C. September 1996. Results of STAR center testing in support of the radioactive bench-scale plasma hearth process: FY96 series I (11/6/95 to 1/18/96). SAIC-96/1018. Science Applications International Corporation, Idaho Falls, Idaho.

Cornelison, C., G.L. Leatherman, J.D. Atkinson, R.D. Woodvine, and F. East. October 1996. Results of STAR center testing in support of the radioactive bench-scale plasma hearth process: FY96 Series II (3/26/96 to 8/2/96). SAIC-96/1017. Science Applications International Corporation. Idaho Falls, Idaho.

Cornelison, C., L.M. DeWitt, and G.L. Leatherman. March 1996. Results of STAR center testing in support of the radioactive bench-scale plasma hearth process system. SAIC-96/1003, Rev. 1. Science Applications International Corporation, Idaho Falls, Idaho.

Dalton, J.D. W.P. Wolfe, and J.A. Batdorf. July 1994. Concepts considered for the plasma hearth process. SAIC-94/1119. Science Applications International Corporation. Idaho Falls, Idaho.

Dalton, J.D., L.M. DeWitt, R.L. Gillins, T. Hertzler, T.L. Huebner, D.D. Nishimoto, B. Packer, and L.J. Slate. August 1995. Conceptual design report for the radioactive field-scale plasma hearth process. SAIC-95/1182. Science Applications International Corporation. Idaho Falls, Idaho.

Demirgian, J.C., Continuous monitoring of the plasma hearth furnace at ANL-W – field test summary report for November 1996. PHP Project Internal Report.

Demirgian, J.C., Continuous monitoring of the plasma hearth furnace at ANL-W – field test summary report for January 1997. PHP Project Internal Report.

Demirgian, J.C.,Continuous monitoring of the plasma hearth furnace at ANL-W – field test summary report for April 1997. PHP Project Internal Report.

Felicione, F.S. September 1998. Analysis of a water-coolant leak into a very high-temperature waste-vitrification chamber", accepted for presentation at *Spectrum '98 International Conference on Nuclear and Hazardous Waste Management*.

Geimer, R.M. and J.A. Batdorf. March 1991. Test plan for the demonstration of the arc-generated plasma treatment of Rocky Flats compacted waste. PHP 000195. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and D.O. Warren. February 1996. Nonradioactive pilot-scale plasma hearth process waste disposition plan. SAIC-95/1335. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and M.M. Larsen. April 1994. Plasma arc treatment of TRU and mixed TRU waste. PHP 000004. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and W.P. Wolfe, May 1992. Treatability study test plan for plasma arc treatment of Rocky Flats compacted waste. SAIC-92/1129. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and W.P. Wolfe. 1993. The plasma hearth process technology development project. PHP 000204. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and W.P. Wolfe. April 1994. Test results from the demonstration of the plasma hearth process. PHP 000003. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., J.A. Batdorf, and W.P. Wolfe. March 1993. Treatability study test plan application to selected DOE waste streams, Revision I. SAIC-92/1228. Science Applications International Corporation. Idaho Falls, Idaho.

Geimer, R.M., R.L. Gillins, and C. Bonzon. August 1994. The plasma hearth process demonstration project for U.S. Department of Energy waste treatment. PHP 000083. Science Applications International Corporation. Idaho Falls, Idaho, for the Metatechnies '94 International Plasma Conference in Bordeaux, France.

Gillins, R.L. and S.D. Poling. February 1995. Radioactive demonstration of the plasma hearth process on spiked and actual low-level mixed waste. PHP 000404. Science Applications International Corporation, Idaho Falls, Idaho, for the Waste Management '95 Conference in Tucson, Arizona.

Gillins, R.L. and S.D. Poling. May 1994. Plasma hearth waste treatment demonstration for radioactive mixed waste. PHP 000013. Science Applications International Corporation. Idaho Falls, Idaho, for the 1994 Incineration Conference in Houston, Texas.

Gillins, R.L. May 1995. Test plan for radioactive testing of the bench-scale plasma hearth process. SAIC-94/1014. Science Applications International Corporation. Idaho Falls, Idaho.

Gillins, R.L. September 1994. The plasma earth process: a versatile solid mixed waste treatment technology. PHP 000090. Science Applications International Corporation. Idaho Falls, Idaho, for the Executive Enterprises Conference on Mixed Waste, in Washington, D.C. and in Seattle, Washington.

Gillins, R.L., September 1995. Plasma hearth process demonstration project. 000590. Science Applications International Corporation, Idaho Falls, Idaho, for the Industrial and Engineering Chemistry Special Symposium of the American Chemical Society in Atlanta, Georgia.

Gillins, R.L., W.E. House, P.L. Pfeiffer, and K.C. Phillips. May 1996. Nonradioactive pilot-scale PHP system readiness assessment plan. SAIC-96/1013. Science Applications International Corporation. Idaho Falls, Idaho.

Hassel, G.R. and Lawrence J. Slate. May 1995. Sampling and analysis plan for the plasma hearth process radioactive bench-scale system. SAIC-95/1142. Science Applications International Corporation. Idaho Falls, Idaho.

Hassel, G.R. January 1995. Preconceptual design report for the plasma hearth process radioactive field-scale system. SAIC-95/1007. Science Applications International Corporation. Idaho Falls, Idaho.

Hassel, G.R. June 1996. Definition of simulated waste feeds for evaluation with the nonradioactive pilot-scale plasma hearth process. SAIC-95/1334. Science Applications International Corporation. Idaho Falls, Idaho.

Hassel, G.R., J.A. Batdorf, R.M. Geimer, G.L. Leatherman, J.M. Wilson, W.P. Wolfe, and A.L. Wollerman. October 1994. Evaluation of the test results from the plasma hearth process mixed waste treatment applications demonstration. SAIC-94/1095. Science Applications International Corporation. Idaho Falls, Idaho.

Hassel, G.R., R.M. Geimer, G.L. Leatherman, and J.M. Wilson. May 1995. Partitioning of radionuclide surrogate and RCRA metals in the plasma hearth process. PHP 000589. Science Applications International Corporation. Idaho Falls, Idaho, for the 1995 International Incineration Conference in Bellevue, Washington.

Hassel, G.R., R.M. Geimer, J.A. Batdorf, and G.L. Leatherman. May 1994. Evaluation of the plasma hearth process for mixed waste treatment applications. PHP 000015. Science Applications International Corporation. Idaho Falls, Idaho, for the 1994 Incineration Conference in Houston, Texas.

Huebner, T. March 1996. SAIC training and access requirements plan for the plasma hearth process radioactive bench-scale demonstration. SAIC-96/1006. Science Applications International Corporation. Idaho Falls, Idaho.

Jackson, T. May 1996. Sampling and analysis plan and quality assurance project plan for the nonradioactive pilot-scale plasma hearth process. SAIC-96/1010. Science Applications International Corporation. Idaho Falls, Idaho.

Leatherman, G.L. and J.D. Atkinson. July 1995. STAR center plasma hearth process testing in support of the radioactive bench-scale design. SAIC-95/1312. Science Applications International Corporation. Idaho Falls, Idaho.

Leatherman, G.L., G.R. Hassel, and J.D. Atkinson. August 1995. Test plan: STAR center testing in support of the nonradioactive pilot-scale plasma hearth process. SAIC-95/1303. Science Applications International Corporation. Idaho Falls, Idaho.

Leatherman, G.L., J.D. Atkinson, C. Cornelison, L.M. DeWitt, G.R. Hassel, K.J. Rebish, and R. Woodvine. October 1995. Results of STAR center testing in support of the nonradioactive pilot-scale plasma hearth process system. SAIC-95/1313. Science Applications International Corporation, Idaho Falls, Idaho.

Leatherman, G.L., J.D. Dalton, S.D. Poling, and W.P. Wolfe. February 1994. Closed loop offgas system - study for the plasma hearth process. SAIC-94/1045. Science Applications International Corporation. Idaho Falls, Idaho.

Leatherman, G.L., R.M. Geimer, J.A. Batdorf, G.R. Hassel, W.P. Wolfe, and K.P. Carney. April 1994. The plasma hearth process: process residuals characterization. PHP 000290. Science Applications International Corporation. Idaho Falls, Idaho, for the 96th Annual Meeting of the American Ceramic Society.

Linder, J.S., P.R. Jang, and L.L. Gresham. 1997. Imaging system operations manual for the Argonne National Laboratory – final report. Diagnostics Instrumentation and Analysis Laboratory, Mississippi State University.

Lord, S.D. and M. Platt. June 1996. Health and safety plan for the nonradioactive pilot-scale plasma hearth process demonstration project. SAIC-96/1000. Science Applications International Corporation. Idaho Falls, Idaho.

Mao, Z.and J.C. Demirgian. June 1996. NO_x and PIC emissions of the plasma hearth furnace at the ANL-W field test. Supplement Report for June 1996, PHP Project Internal Report.

Non-radioactive bench-scale test report, N-IS-1. draft PHP Project Internal Report.

Poling, S.D. and K.J. Rebish. September 1996. Evaluation of the plasma hearth process radioactive bench-scale integrated system operations test series. SAIC-96/1019. Science Applications International Corporation. Idaho Falls, Idaho.

Poling, S.D., J.R. Conner, and J.M. Wilson. August 1996. System design description for the plasma hearth process radioactive bench-scale system process equipment. SAIC-94/1157. Science Applications International Corporation. Idaho Falls, Idaho.

Poling, S.D., L.M. DeWitt, G.L. Leatherman, S.M. Steele, W.P. Wolfe, and A.L. Wollerman. March 1994. Conceptual design report for the plasma hearth process bench-scale radioactive system. SAIC-94/1003. Science Applications International Corporation. Idaho Falls, Idaho.

Power, M.A., O.O. Tolstikhine, and K.P. Carney. PHP model for slag composition and viscosity control, to be submitted to *Journal of Applied Optimal Control*.

Power, M.A., O.O. Tolstikhine, and K.P. Carney. PHP model for slag composition and viscosity control, draft, to be submitted to Journal of Applied Optimal Control.

Science Applications International Corporation. April 1997. Initial bench-scale PHP nonradioactive phase test report. PHP-97/001.

Science Applications International Corporation. August 1994. The plasma hearth process bench-scale experimental unit project description. PHP 000104. Idaho Falls, Idaho.

Science Applications International Corporation. August 1996. Feed material handling and waste disposition plan for the radioactive bench-scale plasma hearth process system. SAIC-94/1159. Idaho Falls, Idaho.

Science Applications International Corporation. December 1996. Startup testing of the PHP pilot-scale system. SAIC-96/1214. Idaho Falls, Idaho.

Science Applications International Corporation. February 1995. Quality assurance project plan for the radioactive plasma hearth process demonstration project. SAIC-94/1111. Idaho Falls, Idaho.

Science Applications International Corporation. January 1996. Quality assurance project plan for the nonradioactive pilot-scale plasma hearth process project. SAIC-95/1336. Idaho Falls, Idaho.

Science Applications International Corporation. January 1997. APCS performance test report. SAIC-97/2700. Idaho Falls, Idaho.

Science Applications International Corporation. June 196. Nonradioactive pilot-scale plasma hearth process training program. SAIC-96/1007. Idaho Falls, Idaho.

Science Applications International Corporation. November 1994. Plasma hearth metal/slag separation testing. SAIC-95/1008. Idaho Falls, Idaho.

Science Applications International Corporation. October 1996. Final test report on the upgraded PHP air pollution control system. SAIC-96/1020. Idaho Falls, Idaho.

Science Applications International Corporation. Plasma hearth process technology development project fiscal year 1994 year-end report. SAIC-94/1141. Idaho Falls, Idaho.

Science Applications International Corporation. September 1995. Plasma hearth process technology development project fiscal year 1995 year-end report. PHP-95/001. Idaho Falls, Idaho.

Science Applications International Corporation. September 1996. Plasma hearth process technology development project fiscal year 1996 year-end report. PHP-96/002. Idaho Falls, Idaho.

Science Applications International Corporation. Test summary and review of environmental requirements for proof-of-principal test in the PHP. PHP 000211. Idaho Falls, Idaho.

"Project Plan for the Radioactive Plasma Hearth Process Demonstration Project," SAIC-96/1011, Science Applications International Corporation, Idaho Falls, Idaho, September 1996.

"The Plasma Hearth Process," SAIC-95/1309, Waste Management Technology Division, Science Applications International Corporation, Idaho Falls, Idaho, November 1995.

Singh, J.P., F. Yueh, H. Zhang, K.P. Carney, and J.R. Krsul. June 1996. A preliminary study of the determination of uranium, plutonium, and neptunium by laser-induced breakdown spectroscopy. Diagnostic Instrumentation and Analysis Laboratory, Document No. DIAL 10575.

Steele, S.M. February 1994. SAIC plasma hearth process demonstration at the Argonne National Laboratory - West TREAT facility: preliminary safety assessment report. SAIC-94/1002. Science Applications International Corporation. Idaho Falls, Idaho.

Sutton, M.A.H., P.J. Crane, D.G. Cummings, and K.P. Carney. May 1995. The evaluation of the X-ray fluorescence (XRF) technique for process monitoring of vitreous slag from thermal waste treatment systems: a comparative study of the analysis of plasma hearth slag for Ce, Fe, and Cr by XRF and inductively coupled plasma spectrometries. Argonne National Laboratory Report No. ANL-ED-001.

Swanson, R.W., M.L. Conley, D.M. Ray, and T.E. Kaczmarek letter. November 19,1997. TREAT operations, to the PHP project, "PHP problem areas and lessons learned. TREAT File 3.34.7.

Wittels, N., G.L. Leatherman, S.D. Poling, J.D. Atkinson, and W.P. Wolfe. August 1995. Analysis of the bench-scale plasma hearth process imaging systems. SAIC-95/1145. Science Applications International Corporation. Idaho Falls, Idaho.

Wolfe, W.P. and S.D. Poling. October 1995. Plasma hearth process hardware development. SAIC-96/1005. Science Applications International Corporation. Idaho Falls, Idaho, for the International Symposium on Environmental Technologies in Atlanta, Georgia.

Wolfe, W.P., R.M. Geimer, and J.A. Batdorf. September 1995. SAIC plasma hearth process pilot-scale system Title II design summary. SAIC-95/1011. Science Applications International Corporation. Idaho Falls, Idaho.

Wollerman, A.L. and C. Cornelison. November 1995. Waste Acceptance Criteria/Guidance for the radioactive bench-scale plasma hearth process. SAIC-94/1158. Science Applications International Corporation. Idaho Falls, Idaho.

APPENDIX C

RISK ASSESSMENT METHODOLOGY

Risk has been measured for eight of the system requirements as defined in the MWFA Systems Requirements Document.

Technically Correct (**Correct**)
The MWFA shall deliver treatment technologies that are technically correct. Operable treatment systems shall be able to: (1) treat target waste streams identified in Federal Facility Compliance Act (FFCA) Site Treatment Plans (STPs) and (2) treat wastes to meet EPA treatment standards (and TSCA or state-regulated treatment standards, where applicable) and comply with the disposal facility Waste Acceptance Criteria.

Technically Complete (**Complete**)
Treatment technologies delivered by the MWFA shall be demonstrated to function as described, and shall be described in sufficient detail so that they may be incorporated into a detailed system design of a mixed low-level or mixed transuranic waste treatment system without further development.

Acceptable to Stakeholders (**Acceptable**)
The MWFA shall deliver mixed waste treatment technologies that are acceptable to the stakeholders.

> Note: The term "stakeholders" means all those who have an interest in the outcome of the MWFA program except the DOE and DOE contractors who have a direct and immediate interest or involvement in the MWFA. Stakeholders include: tribal governments, members of the public, federal, state, and local agencies, universities, and industry.

Acceptable to an End User (**Sponsored**)
The MWFA shall deliver mixed waste treatment technologies to users committed to pursuing the use of those treatment technologies in mixed waste treatment systems.

Permittable
The MWFA shall deliver mixed waste treatment technologies along with sufficient data to show that there are no probable technical reasons to prevent receiving a permit to implement the technology in an operational treatment system. The permit process will be facilitated by involvement with national regulatory organizations such as National Technical Workgroup (NTW) on Mixed Waste Treatment and Interstate Technology and Regulatory Cooperation Subgroup (ITRC). This will include working with the regulators to improve technologies and/or a facility's ability to obtain a permit.

Safe
The MWFA shall deliver mixed waste treatment technologies that can be incorporated into a treatment system and safely operated.

Timely
The MWFA shall deliver mixed waste treatment technologies to enable treatment systems to be designed, built, and operated in time to meet treatment schedules in the FFCA STPs and negotiated in Consent Orders.

Cost
The “delta” refers to the cost of implementation by an end user when compared to the cost analysis included in the Technology Performance Report (TPR). The more closely the cost of implementation compares with cost as reported in the TPRs, the smaller the consequence to the end user of the technology.

Each of the eight system requirements will be addressed independently. Events that can lead to negative consequences relative to implementation of a technology will be identified and assigned to each system requirement. These events will be referred to as “risk factors.” Each technology will be evaluated

independently and relative values for consequences and probability will be assigned to each of the events. The risk factors will be plotted on a risk chart as shown in Figure B-1, Risk Matrix.

The numbers in the matrix elements, 1 through 9, represent the risk with the following scale: 1=very low risk, 2 and 3=low risk, 4, 5, and 6=moderate risk, 7 and 8=moderately high risk, and 9=very high risk. By assigning numerical values to the qualitative matrix elements, total risk can be summed. By assigning the lower values to probability, more emphasis is placed on consequences.

Criteria have been defined for each risk category to allow the user to, as quantitatively as possible, determine the probability and consequence measures to be applied for determination of risk in accordance with Figure B-1.

Figure B-1 - Risk Matrix

Consequence \ Probability	Improbable	Unlikely	Likely
High	6	8	9
Med	3	5	7
Low	1	2	4

Permittable
Permit application is rejected based on regulations that became effective after development of the technology.

The consequences of this scenario will be:

Low if — Treatment process is simple.

Medium if — Treatment process is complex.

High if — Treatment process is highly complex.

The probability of this scenario occurring will be:

Improbable if — An applicable permit has been received.

Unlikely if — Regulators have maintained interaction with developers on this technology during development and demonstration.

Likely if — A permit application has already been rejected for this technology.

Complete
Technology is insufficiently mature to incorporate into a system without additional engineering data.

The consequences of this scenario will be:

Low if — Technology can be deployed without the need for additional testing.

Medium if — Technology can be deployed with limited additional testing and documentation.

High if — Technology requires significant additional development and/or testing to deploy.

The probability of this scenario occurring will be:

Improbable if — Technology successfully meets Stage 5 requirements for full system functionality and has successfully conducted a treatability study.

Unlikely if — Technology successfully meets Stage 5 requirements for full system functionality and has conducted successful demonstration(s) with surrogate wastes.

Likely if — Technology successfully meets Stage 5 requirements for full system functionality, but demonstration/testing program is incomplete.

Acceptable

Native American Tribes and/or public interest groups resist implementation of the technology at DOE sites.

The consequences of this scenario will be:

Low if — Concerns can be addressed by providing additional information about the technology's performance.

Medium if — Concerns center on the performance of the technology; relatively minor modifications to the technology can address the needs and concerns.

High if — Major modifications to the technology are required to address concerns about the performance and ability to solve the problem.

The probability of this scenario will be:

Improbable if — The affected Tribes and public perceive implementation of the technology as resolving an important problem at their site with minimal or no impact to their quality of life, or have not expressed any concerns.

Unlikely if — The affected Tribes and public perceive implementation of the technology as solving an important problem, but having a negative impact on the quality of life.

Likely if — The affected Tribes and public perceive implementation of the technology will not solve an important problem at the site and is perceived to have significant negative impact on the quality of life.

Timely

The technology is not available for implementation by the STP or Consent Order date.

The consequences of this scenario will be:

Low if — Delay in the availability of the technology will not result in missing a milestone in a Consent Order.

Medium if — Need dates for the Consent Order can be renegotiated to accommodate the delay in availability of the technology.

High if — Unavailability of the technology results in missing key milestones in Consent Orders at multiple sites.

The probability of this scenario will be:

Improbable if	Technology development/implementation activities are completed within end-user schedules.
Unlikely if	Need dates identified accommodate any minor delays in technology development activities.
Likely if	Technology does not meet end-user schedules.

<u>Cost</u>

Operational costs are higher than projected.

The consequences of this scenario will be:

Low if	Volume of the targeted waste is low.
Medium if	Volume of the targeted waste is fairly small.
High if	Volume of the targeted waste is very large.

The probability of this scenario will be:

Improbable if	Projections of the technology's cost is based on data from multiple campaigns.
Unlikely if	Projections of the technology's cost is based on data from only one campaign.
Likely if	No actual cost data for the technology on the targeted waste exist.

<u>Sponsored</u>

No end user or commercial entity selects the technology for implementation.

The consequences of this scenario will be:

Low if	Multiple data sets detailing the technology's performance on targeted waste are available.
Medium if	Only limited data are available detailing the technology's performance on targeted waste.
High if	Data are not available detailing the technology's performance on the targeted waste.

The probability of this scenario will be:

Improbable if	Multiple licensing agreements or financial commitments have been made.
Unlikely if	A single licensing agreement or financial commitment for the technology has been made.
Likely if	No commitments have been made or interest shown in the use of the technology.

<u>Correct</u>

Operable treatment systems, which incorporate this technology, are not applicable to target wastes.

The consequences of this scenario will be:

Low if	Volume of targeted waste to be treated is low.
Medium if	Volume of targeted waste to be treated is fairly small.

High if Volume of targeted waste to be treated is very large.

The probability of this scenario will be:

Improbable if Technology developed was tested against multiple waste types.

Unlikely if Technology developed was tested against only one waste type.

Likely if Technology developed was not tested against targeted waste type.

Safe

System failure adversely impacts the health and/or safety of a collocated worker, the environment, or a member of the public.

The consequences of this scenario will be:

Low if Hazardous constituents added or generated by the system are less than the reportable quantities shown in 40 CFR 302.4 and 40 CFR 355, Appendix A.

Medium if Nominal reportable quantities of hazardous constituents shown in 40 CFR 302.4 and 40 CFR 355, Appendix A, are added or generated by the system.

High if Hazardous constituents in quantities 10 times or greater than those listed in 40 CFR 302.4 and 40 CFR 355, Appendix A, are added or generated by the system.

The probability of this scenario will be:

Improbable if System is a benign process, difficult to combust with no natural gas or fuel sources present.

Unlikely if System is a moderately energetic process with natural gas or fuel sources present.

Likely if System is an energetic system (high temperature and/or pressure); large amounts of flammables or pyrophorics.

APPENDIX D

PUBLIC AND TRIBAL INVOLVEMENT RECORD

This appendix contains the detailed information for the activities and documents included in the Tribal and Public Involvement Record. Those items include stakeholder comments, reviews, press releases and articles, presentations, an open house, and other project activities.

PUBLIC AND TRIBAL INVOLVEMENT
The MWFA's strategy to involve Tribes and members of the public is outlined in the MWFA Tribal and Public Involvement Plan and can be obtained on the MWFA homepage at *http://wastenot.inel.gov/mwfa/.*

STAKEHOLDER COMMENTS DATABASE
In addition, the MWFA has assembled a Stakeholder Comments Database that is accessible through the MWFA homepage address. One source in the database contained stakeholder comments specifically on the PHP process. The comments in this source document, *Informal Catalog of Stakeholder Issues Developed for Plasma Hearth Process*, are grouped by keywords and the Develop On-site Innovative Technology's Stakeholder Principles**.** The following examples were results from other keyword searches (e.g., incineration and emissions).

1. **Source**: Tribal and Stakeholder Principles for use in Evaluating Technology Systems for Mixed Low-Level Waste Treatment

   Comment: In developing technologies for application by the MWFA, the effects on human health and the environment should be minimized, including minimizing exposure to workers, potential for release of hazardous and radioactive materials from final storage/disposal products, and the potential for accidents and incidents.

2. **Source**: DOE Report on Rocky Flats Summit II, January 19–20, 1996

   Comment: Storage technology of low-level radioactive waste should include waste minimization and treatment to eliminate, rather than simply stabilize waste.

3. **Source:** Tribal and Stakeholder Principles for Use in Evaluating Technology Systems for Mixed Low-Level Waste Treatment

   Comment: In developing technologies for application by the MWFA, airborne and wastewater effluents that can carry hazardous materials or substances capable of causing adverse human health and environmental consequences should be minimized.

4. **Source:** Report to DOE-OTD prepared by Petersen of Battelle, titled "Possible Stakeholder Concerns Regarding VOC-Arid ID Technologies Not Evaluated in the Stakeholder Involvement Process" (Dec. 1995)

   Comment: Stakeholders care about the extent of energy use to construct, operate, remove, and decommission a technology. A projected energy demand greater than the baseline technology's energy requirements will raise concern, as will the possibility that using the technology and supplying it with energy will place an inordinate demand on or damage natural resources.

   Comment: Stakeholders are greatly concerned about technology failures that cause contaminant emissions or release. They expect careful consideration to be given in technology development or selection decisions to the effects on the environment, the public, or workers from technology failure, ranging from the release of contaminants to mechanical failure and injury. Stakeholders are also very concerned about any uncontrolled emissions or releases of contaminants or other hazardous materials resulting from installation, operation, or removal of a technology. They require detailed

information about the possible impact of releases on people, wildlife, vegetation, air, water, and soil.

REVIEWS
The MWFA assembled a Technical Requirements Working Group (TRWG); a stakeholder group that consists of eight technically trained or conversant members, capable of representing varied Tribal and public perspectives. Some members are participants in specific DOE site stakeholder groups. The TRWG's objective is to assist MWFA technical staff in transforming or integrating site-specific issues, needs, and concerns into the Technology Development Requirements Documents (TDRDs), and providing Tribal and public perspectives to technical staff for identifying and resolving technical issues. The TRWG reviewed and provided recommendations to the MWFA on changes to the Radionuclide Partitioning TDRD (which can be found on the MWFA homepage). Those changes were reviewed and incorporated into the TDRD.

PRESS RELEASES AND ARTICLES
The MWFA quarterly newsletter, March 1997, Volume 1, Issue 1, contained a story titled "Mixed Waste Focus Area Melter Strategy" and an update on the status of the Transportable Vitrification System. The MWFA newsletter has a distribution list that contains DOE-HQ; DOE-ID; EM-30, 40, and 60 personnel; the Community Leaders Network; the TRWG; the National Technical Workgroup; the Interstate Technology and Regulatory Cooperation group; and Site Technology Coordination Groups**.**

PRESENTATIONS
Poster presentations were given at DOE Headquarters and for both houses of Congress on two separate occasions by PHP project team members. Additionally, presentations were made at several key waste management meetings.

OPEN HOUSE
An open house, held at the SAIC Science and Technology Applications Research (STAR) Center, provided the means to brief many area residents and civic leaders about PHP. The Mixed Waste Integrated Programs (MWIP) Headquarters Program Manager and several other folks attended this open house. Members of the Mixed Waste Working Group also toured the STAR Center.

OTHER
In 1994, the National Technical Workgroup selected PHP as a test case for their process and was the subject of a meeting held in Salt Lake City on January 30–31, 1995. The NTW supports development of regulatory permitting procedures for thermal treatment of mixed waste. The members of the group consist of DOE, EPA, NRC, regulating states, and citizen's advisory groups.

Personnel from PHP attended monthly Demonstration Site Implementation Team (DSIT) meetings as stakeholders. The primary objective was to interface with the state regulators on the development of characterization requirements and agreements. The DSIT consisted of regional and local stakeholders specifically concerned about the implementation of the four INEEL technologies selected by the Develop Onsite Innovative Technologies Committee.

PROJECT ACTIVITIES
The PHP personnel participated in many meetings and tours with key stakeholders. They are listed below.

<u>1993</u>	
October	Western Governors Association (WGA)
November	DOE (EM-30, 50), Mixed Waste Treatment Technology Displays
December	DOE (EM-50), program review with Paul Hart (DOE-FETC D&D Program Manager) and State of Idaho RCRA permitting personnel
<u>1994</u>	
January	Develop Onsite Innovative Technologies Committee
February	State of Idaho RCRA permitting personnel and INEEL Oversight Office EG&G EM-30 projects representatives EM-321
April	EM-50 (Jo-Ann Bassi, DOE-HQ) Shoshone-Bannock Tribal representatives

	MWIP Mid-Year Review
	Weapons Complex Monitor Colloquium
May	Rocky Flats waste treatment project personnel
July	WGA Demonstration Site Implementation Team
	State of Idaho RCRA permitting personnel
August	DOE (EM-50) with Paul Hart (DOE-FETC D&D Program Manager)

1995	
October	INEEL Demonstration Site Implementation Team (DSIT) meeting
November	Open House for the assembled bench-scale air pollution control system at the SAIC STAR Center
	INEEL DSIT meeting
December	WGA DOIT Committee meeting

1996	
January	At the request of the MWFA, a group of scientists from Russia toured the STAR center
April	INEEL DSIT meeting
May	A group of nuclear scientists from France toured the bench-scale system at ANL-W
	A group from the Amarillo Center for Plutonium Studies toured the bench-scale system at ANL-W

The PHP personnel produced many papers and publications during FY-94, 95, and 96. A listing can be found in *Fiscal Year 1994 Year-End Report* and *Fiscal Year 1996 Year-End Report* (see the bibliography list in Section 13).

APPENDIX E

ACRONYMS

AMWTP	Advanced Mixed Waste Treatment Project
ANL-W	Argonne National Laboratory-West
APCS	air pollution control system
BNFL	British Nuclear Fuels, Limited
CAA	Clean Air Act
CFR	Code of Federal Regulations
DC	direct current
DOE	Department of Energy
DOE-HQ	Department of Energy-Headquarters
DOIT	Develop Onsite Innovative Technologies
DOT	Department of Transportation
DRE	destruction and removal efficiency
DSIT	Demonstration Site Implementation Team
EM	Environmental Management
EPA	Environmental Protection Agency
FFCA	Federal Facility Compliance Act
FY	Fiscal Year
HEPA	high-efficiency particulate air
H-W	Harbison-Walker
INEEL	Idaho National Engineering and Environmental Laboratory
ITRC	Interstate Technology and Regulatory Cooperation Subgroup
ITSR	Innovative Technology Summary Report
LDR	Land Disposal Restriction
LLW	low-level waste
LMITCO	Lockheed Martin Idaho Technologies Company
MACT	Maximum Achievable Control Technology
MLLW	mixed low-level waste
MTRU	mixed transuranic waste
MWFA	Mixed Waste Focus Area
MWIP	Mixed Waste Integrated Programs
NAAQS	National Ambient Air Quality Standards
NBS	Nonradioactive Bench-Scale
NEPA	National Environmental Policy Act
NESHAPS	National Environmental Standards for Hazardous Air Pollutants
NOD	Notice of Deficiency
NPDES	National Pollutant Discharge Elimination System
NPS	Nonradioactive Pilot-Scale
NRC	Nuclear Regulatory Commission
NSPS	New Source Performance Standards
NTW	National Technical Workgroup
OST	Office of Science and Technology
PG&E	Pacific Gas and Electric
PHP	Plasma Hearth Process
PNNL	Pacific Northwest National Laboratory
POP	proof-of-principle
POTW	publicly owned treatment works
PPE	personal protective equipment
PSD	Prevention of Significant Deterioration
PTC	Permit to Construct
RBS	Radioactive Bench-Scale
RCRA	Resource Conservation and Recovery Act
RWMC	Radioactive Waste Management Complex
SAIC	Science Applications International Corporation
SC	secondary chamber

SRS	Savannah River Site
STAR	Science and Technology Applications Research
STP	Site Treatment Plan
TCLP	Toxicity Characterization Leaching Procedure
TDRD	Technology Development Requirements Document
TMS	Technology Management System
TPR	Technical Performance Report
TRU	transuranic
TRWG	Technical Requirements Working Group
TTP	Technical Task Plan
UTS	Universal Treatment Standard
WETO	Western Environmental Technology Office
WGA	Western Governors Association