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Test Plan for BWID Phase 2 Electric Arc Melter Vitrification Tests

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ABSTRACT

This test plan describes the Buried Waste Integrated Demonstration (BWID), Phase 2, electric arc melter, waste treatment evaluation tests to be performed at the U.S. Bureau of Mines (USBM) Albany Research Center. The BWID Arc Melter Vitrification Project is being conducted to evaluate and demonstrate existing industrial arc melter technology for thermally treating mixed transuranic-contaminated wastes and soils. Phase 1 baseline tests, performed during fiscal year 1993 at the USBM, were conducted on waste feeds representing incinerated buried mixed wastes and soils. In Phase 2, surrogate feeds will be processed that represent actual as-retrieved buried wastes from the Idaho National Engineering Laboratory's Subsurface Disposal Area at the Radioactive Waste Management Complex.

SUMMARY

This test plan describes the Buried Waste Integrated Demonstration (BWID) Phase 2 electric arc melter tests to be performed at the U.S. Bureau of Mines (USBM) Albany Research Center (ALRC). This Arc Melter Vitrification Project is being conducted to evaluate and demonstrate application of industrial arc melter technology for thermally treating mixed transuranic (TRU) contaminated wastes and soils. Phase 1 (baseline) tests were performed during fiscal year (FY) 1993. The Phase 1 treatment processing tests were successfully performed using the existing pilot-scale USBM arc melter waste treatment system on surrogate feed mixtures prepared for "as-incinerated" buried wastes mixed with soil. Surrogates of as-incinerated wastes mixed with soil were used under the premise that in actual treatment practice, an arc melter may be used to vitrify ash generated from previous incineration of the buried waste.

In Phase 2, surrogate feeds will be processed that represent actual as-retrieved buried wastes from the Idaho National Engineering Laboratory (INEL) Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC). These "as retrieved" buried waste feed materials contain substantial fractions of combustible organics. Phase 2 testing will, therefore, evaluate the premise that the arc melter can be used directly for waste treatment without a prior incineration step. Testing of actual bottom ash from a utility refuse-derived furnace (RDF) will also be done during the Phase 2 test series, on behalf of Southern California Edison (SCE). The RDF bottom ash is being provided by SCE. Objectives of the Phase 2 tests include

1. Determine equipment capability to process (a) untreated buried wastestreams, with the ultimate objective to treat the BWID Nominal Standard Wastestream (60 wt% RWMC soil, 15% metal, 10% solid combustibles, 9% absorbed organics, 4% hydroxide sludges, and 2% nitrate sludges) and (b) RDF bottom ash.

2. Evaluate the extent of thermal breakdown and partial oxidation (pyrolysis) in the melter of solid carbonaceous materials and absorbed liquid hydrocarbons in furnace feeds.

3. Determine the effects of and potential for oxidation control in the furnace using air injection through the feed tubes, addition of solid oxidizers in the feed, and/or injection of oxidizer by lancing.

4. Demonstrate complete thermal oxidation of arc furnace offgases and entrained soot in a close-coupled thermal oxidizer.

5. Demonstrate continuous feeding, slag tapping, and as-needed metals tapping capability.

6. Determine composition, homogeneity, and properties of the slag, offgas, and metal products.

7. Evaluate partitioning of a TRU surrogate (Ce), toxic metals, and other elements such as C, Cl, and S among the slag, metal, air pollution control system (APCS) solids, and offgas phases.

8. Determine the effect of cold top (unmelted burden of feed material within the furnace) on furnace process operations, offgas composition, vaporization of metals in the feed, particulate carryover, and furnace performance parameters, with emphasis on reducing metals volatilization, minimizing particulate entrainment, minimizing offgas temperature, and maximizing thermal breakdown of hydrocarbons to simple, noncondensible species.

The main features of the Phase 2 test program include

- Modifications to the existing APCS to enable control of pyrolysis and combustion products and acid gases along with the existing particulate control.

- Preliminary shakedown tests designed to evaluate the furnace and new APCS performance.

- Four days of 24-hour continuous demonstration testing, including 1 day of processing the RDF bottom ash, and 3 days of processing buried waste surrogate mixtures.

- Measurements and sample collection will be performed during the demonstration tests to ensure safe operation, characterize operation of the main system components (feed system, furnace, and APCS) and conduct mass balances to evaluate the fate of feed components such as toxic metals, structural metals, and a TRU surrogate.

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ACRONYMS

AC	Alternating current
ALRC	Albany Research Center
APCS	Air Pollution Control System
ASME	American Society of Mechanical Engineers
BWID	Buried Waste Integrated Demonstration
CEMS	Continuous emissions monitoring system
CVAAS	Cold-vapor atomic absorption spectroscopy
DAS	Data Acquisition System
DC	Direct current
EPA	Environmental Protection Agency
FY	Fiscal year
GFAAS	Graphite furnace atomic absorption spectroscopy
HEPA	High efficiency particulate air
ICAP	Ion-coupled argon plasma spectroscopy
ID	Inside diameter
IEB	Iron-enriched basalt
INEL	Idaho National Engineering Laboratory
LITCO	Lockheed Idaho Technologies Company
MMT	Multiple metal train
PPE	Personnel protective equipment
QA	Quality assurance
QC	Quality control
RDF	Refuse Derived Furnace

RWMC	Radioactive Waste Management Complex
SCE	Southern California Edison
SDA	Subsurface Disposal Area
SOP	Standard Operating Procedure
TCLP	Toxicity characteristic leachability procedure
TRU	Transuranic
TTP	Technical Task Plan
USBM	U.S. Bureau of Mines

Test Plan for BWID Phase 2 Electric Arc Melter Vitrification Tests

1. INTRODUCTION

Substantial quantities (approximately 2.3 million cubic feet) of low-level, transuranic (TRU) and mixed wastes are buried at the Idaho National Engineering Laboratory's (INEL's) Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA).[1] The amount of associated, potentially contaminated soil is estimated at 8 million cubic feet. By volume, combustible materials (wood, paper, plastics, cloth, rags, rubber, etc.) are the largest single category of waste, but there are also large amounts of cemented and uncemented organic and inorganic sludges, nitrate salts, metals, and other noncombustible, nonmetal materials (insulation, glass, soil, concrete, etc.). The wastes are not well characterized or segregated. These wastes and contaminated soils are expected to require treatment to remove or destroy hazardous organics and stabilize the radioactive and hazardous metal constituents. Treatment may also significantly homogenize the wastes and reduce the final disposal volume.

Various treatment technologies are being evaluated and demonstrated for potential application to buried wastes.[2,3,4] The most desirable approach for long-term stabilization of the TRU elements is believed to be high-temperature melting of the waste materials to (a) destroy hazardous organic compounds and (b) dissolve the TRU elements and toxic metals, as oxides, into a slag.[5,6] Upon cooling, the slag will solidify into a durable amorphous glass or crystalline rock-like matrix, depending on composition and cooling rates. The slag can immobilize both the radionuclides and toxic metals in a homogeneous, long-lived waste form. Depending on the physical form of the feed materials, there can also be considerable volume reduction.

This test plan was prepared in accordance with the BWID technology test plan guidance document,[7] but with some deviations which were pertinent to this specific test program. Several of the sections specified in the guidance document not relevant to this program and were excluded. Some other sections have been reorganized so the test plan is more directly focused on the technical test program.

1.1 Technology Description and Background

Industrial arc melter technology is well developed for high-temperature pyrometallurgical field applications[6,7,8] that routinely process large volumes of heterogeneous ore materials similar to buried wastes and soils. Electric arc furnaces are available in a multitude of design configurations for various applications including three-phase alternating current (AC) with three or more electrodes, single-phase AC with two or more electrodes, and direct current (DC) with one electrode at the center and a return under the melt. Power levels up to 105 MW have been built that are capable of processing up to 130 tons/h of ore material. Units such as those built for the processing of phosphorous have been well sealed to prevent influx of undesirable, oxidizing air and/or fugitive emissions. High processing temperatures are possible in the arc furnace. For example, melt processing of refractory oxides, such as magnesia, can achieve temperatures of 2,800°C.

Among arc melter processes, three-phase AC electric arc furnaces have been the most widely used for industrial applications and represent a reliable baseline arc melter technology. Most recently, DC powered configurations have re-emerged in the steel industry as an alternative configuration.

A small, industrial-scale, three-phase AC graphite electrode electric arc furnace located at the Albany Research Center (ALRC) of the United States Bureau of Mines (USBM) is being used for the demonstration tests. This furnace was originally constructed for experimental vitrification of municipal incinerator ash by a consortium organized by the American Society of Mechanical Engineers (ASME).[8] After completion of the ASME tests, the INEL entered into an agreement with the USBM to modify the furnace and use it for testing and developing an arc melter process for vitrification of buried mixed wastes.

1.2 Scope

Unique features of this program include the demonstration of arc melter technology commonly used in industry, using a test facility that is amenable to process and design modifications and performing diagnostic and instrumental measurements. This work, funded by the U.S. Department of Energy's Office of Technology Development through the Buried Waste Integrated Demonstration (BWID), has been planned to proceed in phases. Phase 1, conducted in fiscal year (FY) 1993, was a series of baseline tests on existing equipment with surrogate wastestreams representing previously incinerated waste. In Phase 2, the processing of complex raw feeds materials, including mixtures containing combustible solids and organic solvents, reactive nitrates, and other types of wastes will be evaluated.

In Phase 3, proposed to be conducted based upon the results from Phase 2, more specific evaluation and process optimization will be performed. These technology evaluation tests will provide data needed for designing, building, and operating pilot-scale facilities for radioactive waste treatment testing by FY-97.

1.3 Objectives

The purpose of the BWID Arc Melter Vitrification Project is to evaluate and demonstrate the application of existing industrial arc melter processing technology to the treatment of buried/mixed wastes and soils. Top level objectives for all experimental phases include

- Evaluate and demonstrate application of industrial arc melter processing technology for thermal treatment of mixed TRU contaminated wastes and soils

- Obtain performance data for Environmental Restoration and Waste Management treatment systems design/selection

- Provide data on a large scale for use in developing/verifying analytical tools, models, and scaling relationships for melter system and process design evaluations

- Identify technology gaps and development needs that require closure for deployment of the technology in a production process environment

- Define and evaluate potential process, equipment, and operations improvement modifications.

To meet these overall demonstration program objectives, the objectives of the Phase 2 test include

1. Determine equipment capability to process (a) untreated buried wastestreams, with the ultimate objective to treat the BWID Nominal Standard Wastestream (60 wt% RWMC soil, 15% metal, 10% solid combustibles, 9% absorbed organics, 4% hydroxide sludges, and 2% nitrate sludges) and (b) Refuse Derived Furnace (RDF) bottom ash

2. Evaluate the extent of thermal breakdown and partial oxidation (pyrolysis) in the arc furnace of solid carbonaceous materials and absorbed liquid hydrocarbons in furnace feeds

3. Determine the effects of and potential for oxidation control in the furnace utilizing air injection through the feed tubes, addition of solid oxidizers in the feed, and/or injection of oxidizer by lancing

4. Demonstrate complete thermal oxidation of furnace offgases and entrained soot in a close-coupled thermal oxidizer

5. Demonstrate continuous slag tapping and as-needed metals tapping capability

6. Determine composition, homogeneity, and properties of the slag, offgas, and metal products

7. Evaluate partitioning of a TRU surrogate (Ce), toxic metals, and other elements such as C, Cl, and S among the slag, metal, air pollution control system (APCS) solids, and offgas phases

8. Determine the effect of cold top (unmelted burden of feed material within the furnace) on furnace process operations, offgas composition, vaporization of metals in the feed, particulate carryover, and furnace performance parameters, with emphasis on reducing metals volatilization, minimizing particulate entrainment, minimizing offgas temperature, and maximizing thermal breakdown of hydrocarbons to simple, noncondensible species.

1.4 Technology Agreement

This test plan defines the Phase 2 test series of the BWID Arc Melter Vitrification Project in accordance with the scope of the Technical Task Plan (TTP) No. ID 132010, Revision 0. The technology agreement is based on TTP ID 132011.

2. ORGANIZATION AND RESPONSIBILITIES

The testing will be performed by USBM ALRC with support from Lockheed Idaho Technologies Company (LITCO) consultants, and subcontractors. G. L. Anderson is the Arc Melter Vitrification Project Manager and a co-Principal Investigator. N. R. Soelberg is co-Principal Investigator and will also supervise the Offgas Sampling and Analysis Team during the demonstration tests. Dr. P. C. Turner is the Melter Facility Project Manager, and Dr. L. L. Oden is the Melter Operations Director. Activities and organizational responsibilities include

- APCS modifications: Designs—Enercon, ALRC, and LITCO; vendor equipment purchase (if needed)—LITCO; fabrication and installation—ALRC
- Sample port design and specification—LITCO, with approval and installation by ALRC
- Surrogate waste preparation—ALRC [40,000-lb RWMC soil shipped to ALRC by LITCO and acquisition of additives by ALRC, and shipment of RDF bottom ash to ALRC by Southern California Edison (SCE)]
- Melter test system and facility preparation and operation, process monitoring, process sample collection, and sample analysis—ALRC
- Offgas sampling and analysis, determination of sample analysis requirements, and quality assurance (QA)—ALRC, LITCO with subcontracted sampling team.

2.1 Personnel Support Requirements, Qualifications, and Training

ALRC personnel will direct the test operations and will perform the melter operation, process monitoring, and process sample collection during the planned tests. LITCO personnel will assist the ALRC in test coordination and will direct offgas sampling and analysis. The offgas sampling and analysis will be conducted by ALRC, LITCO, and subcontracted stack testing personnel and equipment. Samples collected will be submitted to ALRC for sample analysis. Laboratory analysis will be performed by USBM at the ALRC laboratories and/or other appropriate laboratories.

ALRC has an experienced team of personnel to run the tests. The ALRC has extensive experience in arc furnace and metallurgical operations, including the design, construction, and operation of the melter facility. The same personnel who operated the melter system for the ASME municipal incinerator ash tests and the FY-93 BWID arc melter demonstration tests will operate the system for the Phase 2 tests. The ALRC analytical laboratory has experienced technicians who have used or pioneered all of the analytical procedures specified for use at the ALRC laboratory. Any analytical procedures that cannot be performed at the ALRC laboratory will be subcontracted to an outside laboratory experienced with the specified procedures and sample matrices. The subcontracted stack testing company will be required contractually to provide engineers and technicians for onsite sampling and analytical support who are experienced in the specific duties.

3. TEST DESCRIPTION

3.1 Facility Description

The melter facility is the same system that was used in the Phase 1 tests, with a completely modified APCS. The APCS had to be revised to enable feed materials with significant amounts of organic material and halogens to be processed. These modifications, sample port installations, and a general description of the modified facility are included in this section. More detailed descriptions of the melter system are provided in the Phase 1 test plan[9] and the Phase 1 data report.[10]

The melter system consists of a continuous feed system, furnace, APCS, and facility power, water, instrumentation, and controls. The feed system, furnace, and thermal oxidizer are shown in Figure 3-1. The APCS is shown in Figures 3-2 and 3-3.

3.1.1 Furnace, Feed System, and Power Supply

The furnace (Figure 3-4) is a stationary, refractory-lined, small industrial-scale, electric arc melting furnace that is sealed for atmosphere control. The furnace has three moveable 4-in. diameter solid graphite electrodes, automatic power, and electrode vertical positioning control. Power is supplied by a fully instrumented 800 kVA three-phase supply. The electrodes are positioned at the apexes of an equilateral triangle 11.25 in. from electrode center to center. The electrodes and four water-cooled feed tubes extend through ports the furnace roof. The feed tubes, furnace roof and sidewalls, and copper slag tapping fixture are water cooled. Slag can be continuously tapped from the furnace; metal is tapped (and the hearth is emptied) through a hole in the bottom center of the hearth.

The furnace shell bottom is lined with 5 in. (2 courses) of chromic oxide-alumina bonded, 90 pct alumina super duty straight firebricks (Ruby) from Harbison-Walker Refractories. Five courses of ruby key bricks shape the hearth and form the sidewall up to the steel shelf that is 28 in. above the bottom and approximately 7 in. above the slag tap hole. One inch of dry phosphate bonds the silicon carbide (SiC) ramming mix (Norton Company) that was placed between the steel bottom and first course of ruby straights to improve heat transfer to the bottom. One inch of the ramming mix is also placed between the ruby keys and sidewall for heat transfer improvement. The upper sidewall is lined with 4.5-in. GM 70 DE (70% alumina) insulating fire brick from North American Refractories. Fiberfrax batting (Carborundum Company) 1 in. thick is placed between the sidewall and arch brick as added insulation. The hearth is rammed to 6 in. deep at the center with Ruby ramming mix from Harbison-Walker. The roof is lined with 4 in. of Narphos 85P plastic refractory (85% alumina) from North American Refractories. The finished inside diameter of the furnace is about 46 in. at mid-height. The capacity of the hearth is approximately 5 ft^3.

The metal tap hole is 1.5 in. in diameter. The copper, water-jacketed tapping fixture is 6 in. outside diameter and 7.5 in. long, with a tap hole diameter of 5/8 in.

The carbon steel shell of the furnace is 65 in. high and tapers from 60 in. inside diameter (ID) at the bottom to 56-in. ID at the top. Three carbon steel straps (2 in. wide × 0.060 in. thick) were welded to the inside bottom of the shell in a triangular array before placing the refractory lining in

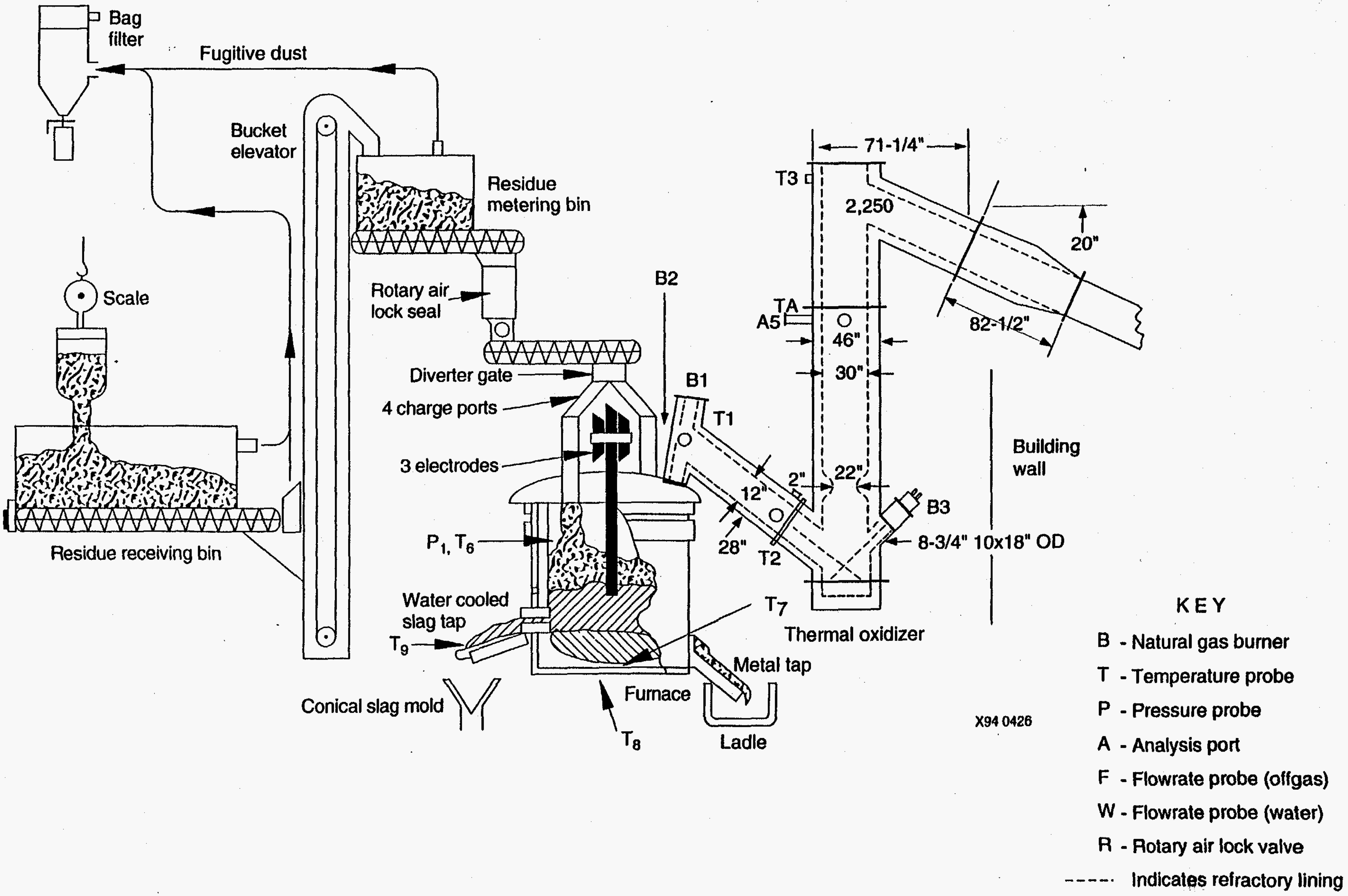
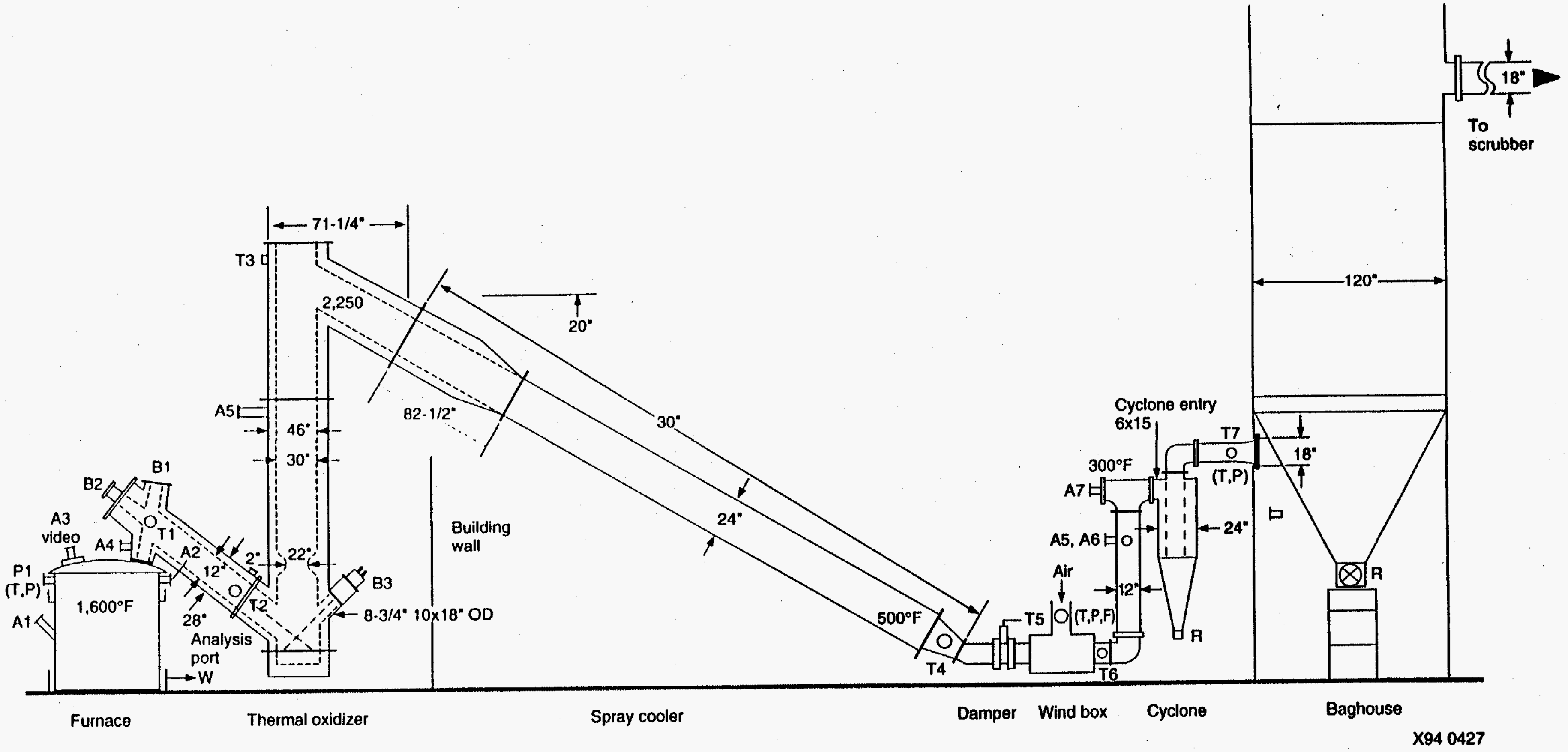


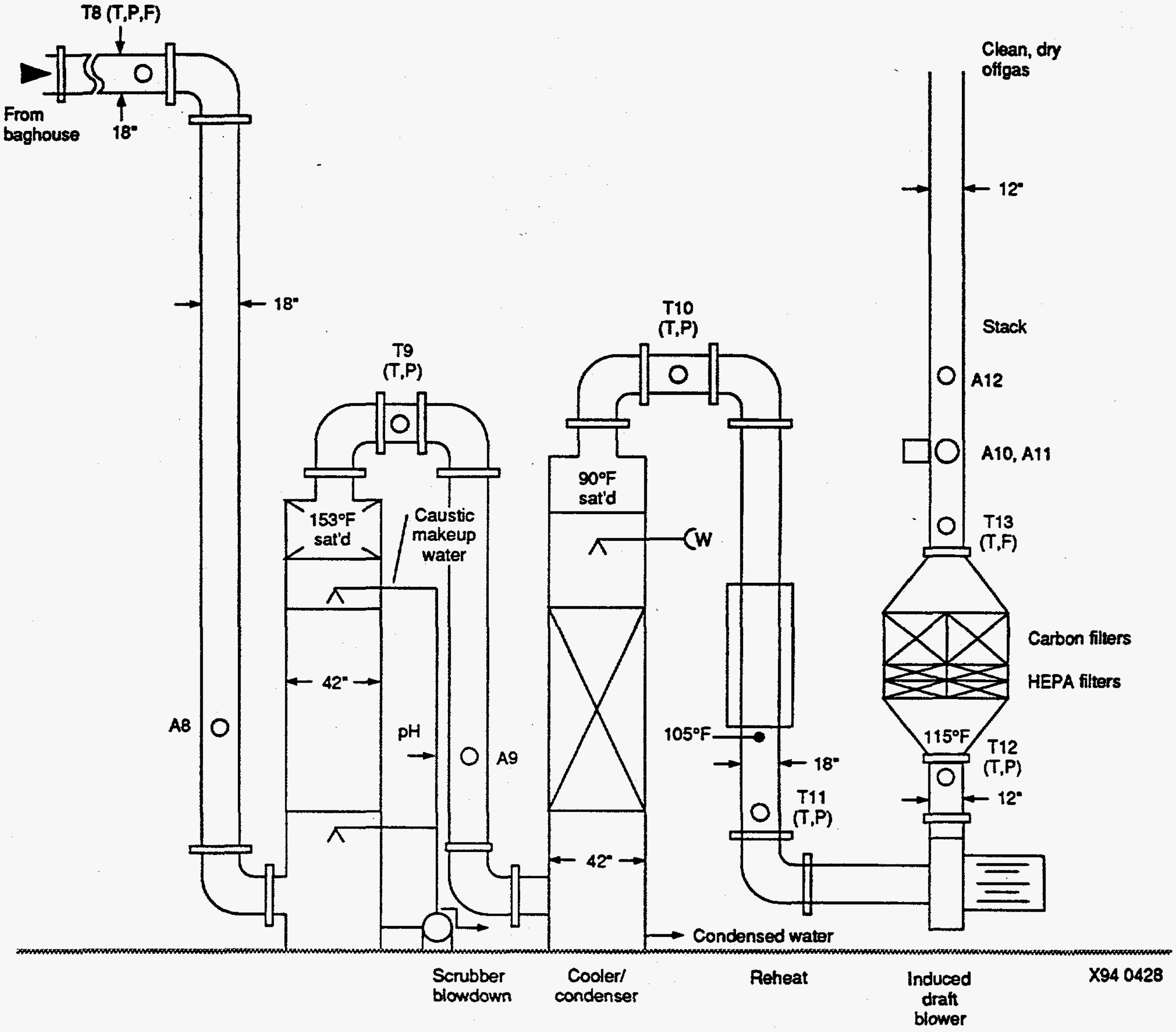
Figure 3-1. Schematic of the feed system, furnace, and thermal oxidizer.



KEY

B - Natural gas burner
P,T - Temperature, pressure port
A - Analysis port
F - Flowrate probe (offgas)
W - Flowrate probe (water)
R - Rotary air lock valve
------- Indicates refractory lining

Figure 3-2. Schematic of the offgas system from the furnace to the baghouse.



KEY

T - Temperature probe
P - Pressure probe
A - Analysis port
F - Flowrate probe (offgas)
W - Cooling water flowrate
CW - Cooling water

Figure 3-3. Schematic of the offgas system downstream of the baghouse.

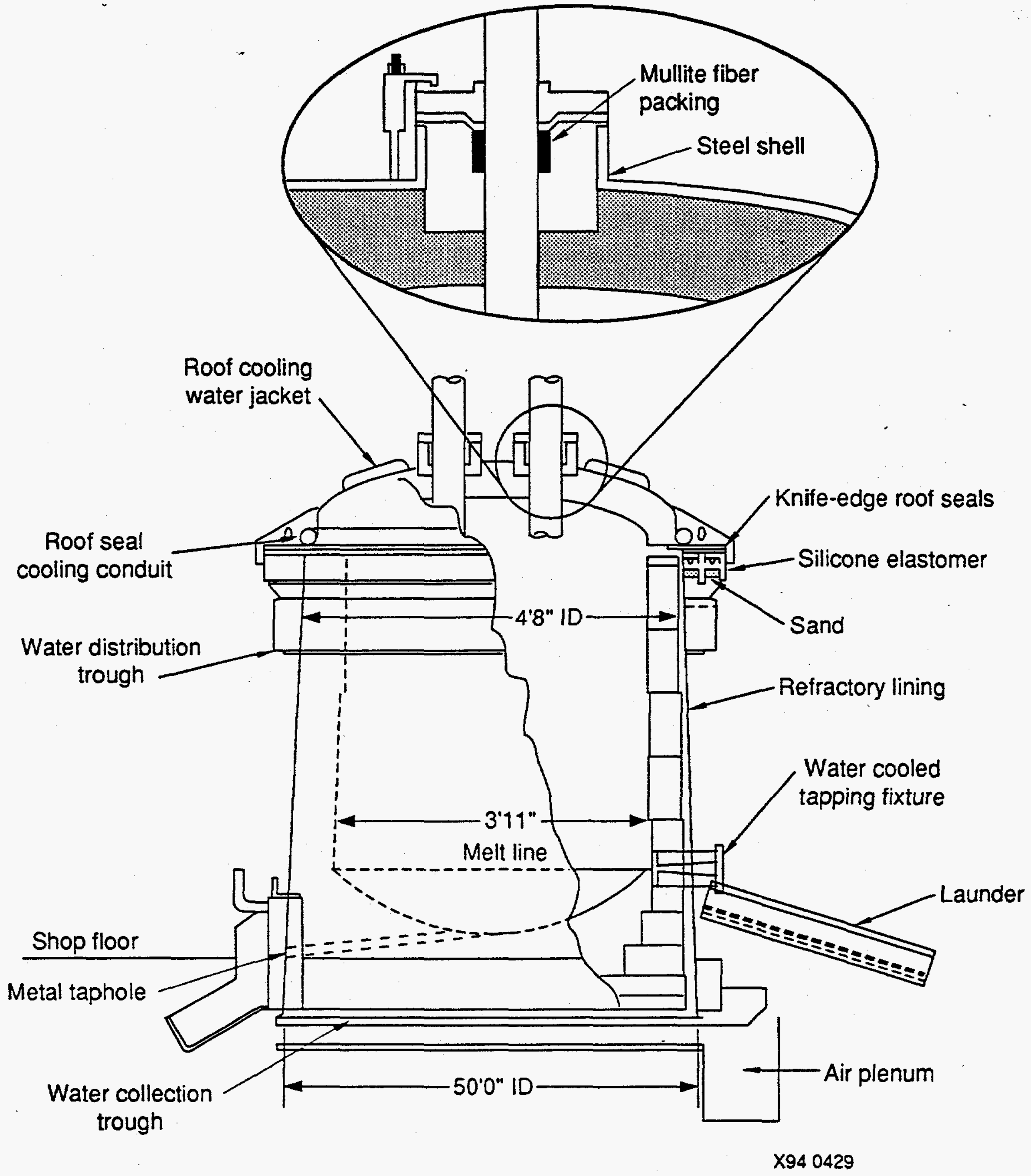


Figure 3-4. Schematic of the arc melter furnace.

the shell. These straps were worked between the bricks and through the refractory ramming mix during construction of the hearth to provide an electrical circuit to ground between each pair of electrodes. The furnace shell was then securely grounded on the outside.

The base of the furnace is cooled by air flowing at about 1,300 cfm through a plenum formed by six, 4-in. high "I" beams on which the furnace rests. The furnace shell, roof, slag tap hole, slag launder, metal tap hole collar, power supply transformer, and electrode arms, cables, and clamps are all water cooled. Cooling water is pumped to the furnace from a 1,500 gal, cool water sump by a 15 hp centrifugal pump. The furnace shell is cooled by a curtain of water (50 gpm) cascading down the exterior wall from the annular distribution trough near the shell top. All cooling water is collected at the base of the furnace in a trough and is returned by gravity to a 1,500 gal, warm water sump through a 6-in. polyvinyl chloride line. Water is pumped from the warm water sump to a Marley Model NC-111 cooling tower with a cross-flow induced draft design. The cooling tower supplies up to 150 gpm of water at 74°F with 142°F maximum return temperature and 70°F wet bulb ambient air temperature.

City water is available for emergency cooling in case of general power failure or pump malfunction. The most critical component is the copper, water-cooled slag tap hole (cinder monkey), which is in direct contact with molten slag while the furnace is operating. All other components should not be damaged by loss of water if furnace power is shut off. A flowmeter in the water circuit to the cinder monkey de-energizes and opens the automatic valve in the city water line if power fails or the flowrate from the cooling tower decreases below 20 gpm in that circuit.

3.1.2 Air Pollution Control System

The new APCS is designed to completely oxidize the furnace offgases and control particulate, toxic metals, and acid gas emissions. The APCS will include

- A thermal oxidizer, close-coupled to the melter, designed for a maximum temperature of 2,400°F. Two natural gas burners are located between the outlet of the furnace, and a third burner is located near the inlet of the thermal oxidizer.
- A water spray cooler for initial temperature quenching to 500°F, followed by an air-dilution temperature quench section for cooling to 300°F.
- A cyclone for removing coarse particulate upstream of the baghouse.
- A pulse-jet baghouse for particulate removal.
- A wet scrubber for acid gas (primarily HCl and SO_2) removal, with a design gas outlet temperature of around 153°F.
- A cooler/condenser for further offgas cooling and removing condensed water droplets, with a design outlet temperature of 90°F.

- A resistance-heated reheater to raise the offgas above the dewpoint, with a design gas outlet temperature of 105°F. The reheater is necessary to prevent moisture condensation in the downstream equipment and to minimize the steam plume at the stack outlet.

- A high efficiency particulate air (HEPA) filter

- An activated carbon filter for controlling Hg and other gaseous toxic metals and contaminants.

The baghouse for this system is the same existing baghouse used in the Phase 1 tests. The baghouse was designed for operation in the temperature range of 250 to 400°F. There are 47 Gortex-membrane Teflon-coated fiberglass bags, 4.5 in. diameter × 10 ft long. These bags are rated to remove 99.98% of particulate greater than 0.3 μm. Bags are cleaned with a back pulse-jet of air at 100 psig. This baghouse is rated for a maximum gas flowrate of 2,000 acfm. Additional particulate filtration is provided downstream of the baghouse by a HEPA filter unit, also rated to remove 99.98% of particulate greater than 0.3 μm.

3.1.3 Phase 2 Facility Modifications

To enable the processing of surrogate waste mixtures containing combustibles, metals, nitrates, hydroxides, and solvents, a number of modifications are being made before the shakedown and demonstration tests. These are summarized as follows:

- The length of the receiving bin will be decreased to 6 ft to diminish classification and segregation of feed materials by the feed screws.

- A sloping deck screen will be added between the receiving bin and bucket elevator to remove objects with large aspect ratios. Screw conveyors are prone to fouling if the major diameter of particles within the feed mixture exceeds the clearance between screw and housing. The ash residues from SCE may contain objects with large aspect ratio.

- The four water-cooled feed tubes will be connected to a single-metered air supply. Combustion air will be injected through the feed tubes to provide oxidizing agent uniformly near the surface of the molten slag.

- The furnace hearth will be relined with Ruby ramming mix. Sidewall and roof refractory are in satisfactory condition.

- The APCS described in Section 3.1.2 is an extensive modification of the prior APCS used in the FY-93 tests, with an added thermal oxidizer, spray quench section, cyclone, larger baghouse, wet scrubbing, reheating, and charcoal filtration.

3.1.4 Sample Locations and Sample Ports

The offgas monitoring and sample collection program for the demonstration tests will be extensive to characterize furnace emissions and APCS performance. Penetrations are planned for sample ports at the locations specified in Table 3-1. Sample ports upstream of the ID fan will be

Table 3-1. Furnace and APCS sample locations and ports.

Location	Port no.	Port specification	Possible kinds of measurements
Existing port in furnace sidewall	A1	1.5-in. nom. pipe w/ball valve and cap	Bath temperatures, gas temperatures, O_2, CO_2, CO, THC, slag/metal samples
Furnace upper sidewall above water trough	A2	1.5-in. nom. pipe w/ball valve and cap	Gas temperatures, O_2, CO_2, CO, THC, particulate, metals, particle size
Furnace upper sidewall above water trough	P1	—	Continuous furnace pressure, temperature
On the existing door on furnace roof	A3	4-in. nom. flanged port with pipe w/ball valve and cap	Visual observations with video camera
In furnace outlet duct	A4	1.5-in. nom. pipe w/ball valve and cap	Gas temperatures, O_2, CO_2, CO, THC, particulate, metals, particle size
At crossover	T1	—	Continuous gas temperature - pilot burner control thermocouple tied to pilot burner (B1)
In wall of thermal oxidizer inlet duct	T2	—	Continuous gas temperature - control thermocouple for crossover duct burner (B2)
In wall of thermal oxidizer near outlet	A5	2-in. nom. pipe w/ball valve and cap	Gas temperatures, O_2, CO_2, CO, THC, particulate, metals, particle size
Thermal oxidizer outlet (spray cooler inlet)	T3	—	Continuous gas temperature
Spray cooler outlet (dilution quench inlet)	T4	—	Continuous gas temperature
Dilution air inlet duct	T5	—	Continuous dilution air pressure, temperature, flowrate
Dilution quench outlet (cyclone inlet)	T6	—	Continuous offgas pressure, temperature
Dilution quench outlet (cyclone inlet)	A5, A6	3-in. nom. pipe w/ball valve and cap; location per EPA specifications	Gas temperatures, O_2, CO_2, CO, THC, particulate, metals, particle size

Table 3-1. (continued).

Location	Port no.	Port specification	Possible kinds of measurements
Flanged T at cyclone inlet (cyclone inlet)	A7	2-in. nom. pipe w/ball valve and cap	Gas composition
Cyclone outlet (baghouse inlet)	T7	—	Continuous gas pressure, temperature
Baghouse outlet (scrubber inlet)	T8	—	Continuous gas pressure, temperature, flowrate
Baghouse outlet (scrubber inlet)	A8	2-in. nom. pipe w/ball valve and cap	Gas composition
Scrubber outlet (cooler/condenser inlet)	T9	—	Continuous gas pressure, temperature
Scrubber outlet (cooler/condenser inlet)	A9	2-in. nom. pipe w/ball valve and cap	Gas composition
Cooler/condenser outlet (reheater inlet)	T10	—	Continuous gas pressure, temperature
Reheater outlet (ID fan inlet)	T11	—	Continuous gas pressure, temperature
HEPA filter inlet	T12	—	Continuous gas pressure, temperature
Stack	T13	—	Continuous gas pressure, temperature, flowrate
Stack	A10, A11	3-in. nom. pipe w/cap; location per EPA specifications	Particulate, metals
Stack	A12	2-in. nom. pipe w/ball valve and cap	Gas composition

designed to minimize air inleakage due at the design negative pressure of around 0.5 in. in the furnace up to around 10 in. at the inlet of the ID fan. Minimizing air inleakage will reduce the amount of pressure and flowrate excursions in the furnace and APCS and improve worker safety.

3.2 Test Program

During the field test, instrumentation will be monitored and samples will be collected to characterize the performance of the melter and offgas systems. The test matrix is shown in Table 3-2. Table 3-3 shows the types of measurements and samples that will be collected for each of the test conditions. Operating parameters that will be varied during the test program are

- Feed mixture [RDF ash with and without an asbestos surrogate and BWID nominal waste surrogate mixture with varying (decreasing) amounts of added soil]
- Cold top (with and without)
- Oxidant addition [solid (nitrates and mill scale) in feed, and air lanced in through the feed tubes or lance—off/on and also rate]
- Power density.

These parameters are related to the ability of the furnace to process real wastes that contain various metals that may be volatile and organics that include both volatile organic and fixed carbon components. Varying the cold top and power density can affect the volatilization of metals, while oxidant addition will affect the oxidation of the fixed carbon. Volatile organics will evolve with or without oxidant addition.

The ability to form a ceramic waste will also be evaluated by using 2 TC-instrumented drums for slow-cooling the slag while monitoring the temperatures and cooling rates at different locations in the drums. Analyses of these drums will be used to evaluate the formation of crystalline structures at different cooling rates.

Operating parameters that will not be purposely varied (but they may vary during the tests) and will be monitored include

- Afterburner temperature
- Baghouse dP, cleaning cycle, temperature, and cloth/gas ratio
- Scrubber parameters [recycle rate, make-up rate, caustic/(SO_2 + HCl) ratio, gas/liquid ratio]
- Carbon absorber parameters (gas flowrate/surface area ratio, hours operated on same charcoal, and temperature)
- Redox conditions in the slag and plenum (excess O_2 in the plenum just above the melt; slag and metal C content and Fe^{+2}/Fe^{+3} ratio)

Table 3-2. Test matrix for the demonstration tests.

Day	Test duration (hours)	Test start/stop	Test no.	Test objective	Feed mixture	Cold top	Oxidant addition
1	10	1000/1800 tap metal hole	1	RDF bottom ash demonstration	RDF-0, bottom ash with fluidizer	Y	N
1	10	2000/0400 tap metal hole	1	RDF bottom ash w/asbestos surrogate	RDF-10A, bottom ash spiked with serpentine	Y	N
2	6	0600/1000 end melt	2	Stepwise increase of nominal waste mixture in soil	Nom-90, 90% soil, 10% nominal waste surrogate	Y	Stoic air through feed tubes for CO
2	6	1200/1600 end melt	2	Stepwise increase of nominal waste mixture in soil	Nom-80-1, 80% soil, 20% nominal waste surrogate	Y	Stoic air through feed tubes for CO
2	6	1800/2200 tap metal hole	2	System performance evaluation	Nom-80-2, 80% soil, 20% nominal waste surrogate	Y	Stoic air through feed tubes for CO
3	6	0000/0400 tap metal hole	2	Stepwise increase of nominal waste mixture in soil	Nom-70-1, 70% soil, 30% nominal waste surrogate	Y	Stoic air through feed tubes for CO
3	6	0600/1000 end melt	2	Stepwise increase of nominal waste mixture in soil, lower power density and feedrate	Nom-60-1, 70% soil, 30% nominal waste surrogate with added mill scale	Y	Stoic air through feed tubes for CO
3	6	1200/1600 tap metal hole	3	Added solid oxidant in feed	Nom-60-2, 70% soil, 30% nominal waste surrogate	Y	Substoic air through feed tubes for CO
3	6	1800/2200 tap metal hole	3	Added air through lance for oxidizing metal and fixed carbon	Nom-60-3, 60% soil, 40% nominal waste surrogate	Y	Substoic air through feed tubes for CO
4	6	0000/0400 tap metal hole	3	Operate without cold top	Nom-60-4, 60% soil, 40% nominal waste surrogate with added mill scale	N	Stoic air through feed tubes for CO

Note: Depending on results of the shakedown tests and from days 1–3 of the demonstration tests, the test conditions may be modified by more rapidly decreasing the proportion of soil and additives in the feed, to obtain test results at soil proportions less than 60%.

Table 3-3. Sample collection and measurement matrix for the demonstration tests.

			Process samples			Furnace measurements^{a,b}		APCS measurements^{a,b,c,d}		
Day	Test start/ stop	Feed mixture	Slag tap	Metal tap	APCS^d	In-furnace	Furnace out	Baghouse out	Condenser out	Stack
1	1000/1800 tap metal hole	RDF-0	Y	Y	Y	Radial and axial xverse (T, PG, NO$_x$)	V, T, PG, THC, MMT-SP, SF, GC			GC, AG
1	2000/0400 tap metal hole	RDF-10A	Y	Y	Y	Radial and axial xverse^e (T, PG, NO$_x$)	V, T, PG, THC, MMT, SF			GC, PG, MMT
2	0600/1000 end melt	Nom-90	Y	N	Y		V, T, PG, THC, GC	PG, THC, AG		GC, AG
2	1200/1600 end melt	Nom-80-1	Y	N	Y		V, T, PG, THC, SF	PG, THC, AG		GC, AG
2	1800/2200 tap metal hole	Nom-80-2	Y	Y	Y	Radial and axial xverse (T, PG, NO$_x$)	V, T, PG, THC, MMT-SP, GC	PG, THC, AG		GC, AG
3	0000\0400 tap metal hole	Nom-70	Y	Y	Y		V, T, PG, THC			GC
3	0600\1000 end melt	Nom-60-1	Y	N	Y	Radial and axial xverse (T, PG, NO$_x$)	V, T, PG, THC, MMT-SP, Cl_2, GC	PG, THC, AG		GC
3	1200/1600 tap metal hole	Nom-60-2	Y	Y	Y	Radial and axial xverse (T, PG, NO$_x$)	V, T,PG, THC, MMT-SP, Cl_2, GC			GC
3	1800/2200 tap metal hole	Nom-60-3	Y	Y	Y	Radial and axial xverse (T, PG, NO$_x$)	V, T,PG, THC, MMT, GC	PG, THC, AG		GC, PG, AG, MMT

Table 3-3. (continued).

			Process samples			Furnace measurements[a,b]		APCS measurements[a,b,c,d]		
Day	Test start/ stop	Feed mixture	Slag tap	Metal tap	APCS[d]	In-furnace	Furnace out	Baghouse out	Condenser out	Stack
4	0000/0400 tap metal hole	Nom-60-4	Y	Y	Y	Radial and axial xverse (T, PG, NO_x)	V, T, PG, THC, MMT, GC	PG, THC, AG		GC, PG, AG, MMT

a. If possible, additional measurements such as in-situ particle sizing and FTIR gaseous analysis will also be performed at selected locations. Inclusion of additional analysis may prevent the performance of some analyses such as the Cl_2 analysis. Also, the number and types of furnace and APCS measurements may change due to (a) operating information obtained during shakedown tests, (b) changes in the test matrix, or (c) limited BWID funding.

b. Measurements include V (velocity and flowrate), T (temperature), SF = Slagging/fouling potential, PG (permanent gases O_2, CO_2, CO), AG (acid gases NO_x, SO_2, HCl), THC (total hydrocarbons), GC (gas chromatograph analysis for O_2, CO_2, CO, Ar, N_2, H_2, C_1-C_4, CCl_4, and TCE), MMT (multiple metals train for particulate and metals), MMT-SP (MMT modified for single point, abbreviated sampling to obtain grab samples of solids and vaporized materials).

c. Continuous O_2 measurement is made at the outlet of the spray quench unit in addition to the above listed measurements for thermal oxidizer control.

d. APCS samples = Solid samples collected from all collection points in system (particularly from the thermal oxidizer, spray quench and baghouse).

e. xverse = traverse across a diameter or radius for sample collection or measurements at discrete sample points.

- Feedrate and power levels

- Furnace offgas flowrate, temperature, composition

- Slag temperature, viscosity, basicity

- Entrained and volatilized particulate.

3.2.1 Feed Mixtures

The feed mixtures will be prepared to test the operation of the melter system with bottom ash from the SCE RDF and mixtures of surrogate buried wastes and soil at the INEL RWMC. The RDF bottom ash will be tested with and without the addition of 10 wt% serpentine as a surrogate for asbestos. The composition of the RDF bottom ash mixtures will be determined by analysis at the ALRC.

The two mixtures of RDF bottom ash will be tested in 2 test days, 1 day for each mixture. The bottom ash will likely require pelletization before to melting for better dust control during feeding and handling. Pelletization will likely require moisture addition but may not require the addition of a binder. A drying step must follow pelletization. The decision to pelletize will be made following examination of the ash.

The surrogate buried waste mixtures will simulate the BWID nominal waste mixture mixed with soil. The target proportion of soil in the mixture is 60%, but the actual maximum proportion used for the demonstration tests will be determined during the shakedown test and during the initial buried waste demonstration tests. For the demonstration tests, the actual feed mixture will be varied slightly to evaluate melter system operation with and without solid nitrate oxidants. The surrogate buried waste mixtures will also be buffered with lime (CaO) additive to a molar basicity of 0.7.

The composition of the buried waste materials is shown in Table A-1 in Appendix A. These waste materials include metals, solid combustibles, silicated organics, nitrate salts, and metal hydroxide sludges. The BWID nominal composition is a weighted average blend of these materials. The surrogate buried waste feed mixtures will be prepared by ALRC from representative materials blended with RWMC soil and pebble lime. The target compositions of the nominal buried waste in mixtures with 60 to 90% soil (denoted Nom-60 to Nom-90) are shown in Table A-2. The target amounts of volatile and combustible materials and elemental metals in these mixtures are summarized in Table A-3. The estimated amounts and composition of the offgases generated from melting the surrogate waste mixtures are shown in Appendix B. The estimated compositions of the surrogate additives used to prepare the surrogate waste mixtures are shown in Appendix C.

3.2.2 Test Uncertainties

The greatest uncertainties for this test program are the (a) melter system performance characteristics while processing the surrogate INEL waste feedstreams, (b) ability to perform some of the planned diagnostics and sample collection, and (c) available funding. These uncertainties specifically include

- Feeding the mixtures containing a variety of materials of different sizes (less than 3/8 in.), shapes, and densities. Challenges include minimizing stratification, controlling dust evolution from the feed system, controlling and monitoring the feedrate, and blockage at auger locations, feed tubes, and other points.

- Performance of the melter when processing feed mixtures containing large amounts of volatile organics, fixed carbon, and nitrates. Challenges include pressure fluctuation control, volatilization of volatile materials, oxidation of fixed carbon, minimization of soot deposition in the furnace (that may interfere with arc performance), and deposition of other materials.

- Performance of the air pollution control system. Challenges include minimizing fouling deposits throughout the system, achieving efficient oxidation of organics in the thermal oxidizer, sufficient offgas cooling to protect the baghouse without excessive cooling and resultant moisture condensation, and efficient particulate and acid gas control.

- Performance of monitoring and sample collection equipment. Measurements and sampling are planned for many different locations in the melter system including the furnace and selected locations in the APCS. Due to high temperatures and high levels of entrained particulate at these locations, the success of some of the measurement and sampling methods will need to be demonstrated during the shakedown test and demonstration tests.

- Ability to perform measurements at locations between the furnace outlet and thermal oxidizer outlet. The presence of burner flames will impact the ability and interpretation of measurements, so burners will be turned off if having the burners off is considered a safe practice.

The test program and QA program have been developed to specifically address these uncertainties. As much as is reasonably possible, melter system performance and configuration of the offgas sampling and analytical equipment and procedures will be evaluated in the shakedown tests. These evaluations will include measuring temperatures, velocities, gaseous composition, and particulate levels in the furnace and at the furnace outlet, baghouse outlet, and stack. Samples of slag and metal (if produced) will be collected during tapping and, if necessary, through ports in the furnace. Samples of APCS solids will be collected at all collection points in the APCS. Following the shakedown test, the melter system will be inspected for indicators of feed plugging, fouling, erosion, corrosion, and any other visible conditions.

There may be insufficient funding to perform the full scope of test measurements and sample collection described in Section 3.2. Engineering judgement and results obtained in the shakedown tests and initial demonstration tests will be used to limit the scope of testing to available funding.

3.2.3 Contingency Plans

Contingency plans for potential undesired occurrences include identifying (to the extent possible) the cause of the occurrence and taking steps to prevent recurrence. Depending on the circumstance, resolution may include equipment or operational changes to correct the situation or revising the test plan to avoid the occurrence. Test plan revisions may be done by and with the approval of the onsite test team leaders, and documented in test log notes. Such revisions will be made only when needed to ensure safe operations and maximize the amount and quality of the test results.

Feed system problems must generally be resolved for continued testing by more direct manual interaction, equipment modifications, or changing the feed mixture. Furnace problems can vary widely but can often be remedied by adjusting the feedrate or power levels, electrode control (rheostat), or feed mixture composition. Adjustments are also available for all components of the APCS to optimize the performance of the thermal oxidizer, cooler, baghouse, scrubber, charcoal filter, and HEPA filter.

Furnace plenum and APCS sample collection and monitoring procedures may require modification for better suitability for the sample locations, available sampling time, and offgas conditions. It may be necessary to significantly modify some of the in-furnace and furnace outlet sampling and analysis procedures because of temperature and particulate conditions in the offgas and to avoid, or account for, the three gas burners in the system. Such modifications, if necessary, will be made to meet the goals of the test program within limitations of those procedures.

4. SEQUENCE OF ACTIVITIES

The success of the baseline tests depends on the performance of many activities by the USBM ALRC and INEL. The demonstration tests cannot be performed until completion of several activities. These activities include

- APCS modifications: (a) designing overall system, (b) designing individual components, (c) purchasing or fabricating APCS components, (d) installation, (e) fabricating and installing sample ports, and (f) operational testing

- Feed system modifications: (a) shortening the receiving bin length, (b) fabricating and installing the sloping deck screen, (c) fabricating and installing the feed tube air injection system, and (d) designing and fabricating the air lance

- Furnace preparations: (a) refractory casting, (b) added instrumentation, (c) final assembly, and (d) operational checkout

- Feed mixture preparations: (a) shipping RDF bottom ash, (b) acquisition of buried waste additives, (c) sample analysis of RDF bottom ash, soil and feed additives, and (d) mixing the feed materials as determined prior to the demonstration tests

- Screening tests in the "W" furnace for evaluating refractory performance, melting temperatures, offgas emissions, and safety

- Shakedown test

- Review and revisions following shakedown test

- Demonstration tests

- Post-test activities: (a) equipment inspections, (b) data management, and (c) sample handling and analysis

- Field data report and draft and final data evaluation reports.

This document is not a controlling document for project test schedule. For information purposes, the estimated sequence of events is as follows:

Activity
Overall APCS system design—Completed
Milestone: APCS design meeting, Denver, CO—Completed in October 1993
Design of individual APCS components—Completed
Draft of test plan—Completed
Placing on order all APCS components—Completed
Feed mixture preparations
Feed system modifications
Furnace preparations
"W" furnace screening tests
Receiving all APCS components
Installation of furnace and APCS modifications
Final test plan
Initial shakedown test
Final shakedown test
Demonstration tests
Post-test sample and data handling
Quick look field data test report
Laboratory sample analyses
Test results report

5. MEASUREMENTS AND SAMPLE COLLECTION

The sampling and analysis plan is provided in this test plan rather than in the technology test plan. There is currently insufficient BWID funding for the full scope of sample collection and analysis described here. Furthermore, some of the measurements described here may be deleted based on results of the shakedown tests, while other measurements may be added. Sound engineering judgement will be used to perform the testing within the funding available at the time of the demonstration tests and meet the test objectives.

5.1 Melter Furnace Process Continuous Monitoring

Facility process monitoring and data acquisition will be performed using a computer data acquisition system (DAS) and by using manually recorded logs and data sheets. Printouts of the DAS-recorded data will be automatically made every 2 minutes. The monitored parameters are summarized in Table 5-1.

5.2 Process Sample Collection

Process material samples that will be collected during or after each test are summarized in Table 5-2. Analytical results of these samples will be used to (a) perform process material mass balances, (b) determine product phase partitioning and fate of metal and surrogate TRU elements in the feed, (c) determine if the secondary product (APCS) streams are hazardous, and (d) evaluate the physical and chemical properties of the vitrified slag and metal phases. Process sample collection and handling procedures are summarized in Table 5-3.

5.3 Gaseous and Particulate Measurements and Sample Collection

Gaseous and particulate measurements and sample collection, in addition to the process monitoring and sample collection described in Sections 5.1 and 5.2, will be conducted at selected locations in the furnace and the APCS. Gaseous measurements will include velocity, temperature, and composition measurements. Particulate measurements will include slagging/fouling potential, total particulate, and metals. The total particulate and metals determinations will be done using the draft EPA Method 29, or MMT, modified to include measurement of total particulate in addition to metals. All measurements in the high-temperature areas upstream of the spray cooler will be done using water or air-cooled sample probes. Gaseous and particulate measurement and sample collection procedures are summarized for the different sample locations in Table 5-4. Sampling periods of up to several hours for each test condition may be required to complete the planned scope of sample collection and offgas measurements.

Sample collection and measurements using probes inserted through sample ports upstream of the ID fan can affect the furnace and APCS operation by allowing ambient air leakage into the system if the sample ports are not well sealed around the sample probes. Negative pressures (draft) of around 1-in. or more are necessary in the furnace to prevent hot, noxious plenum gases into the work area. The draft will increase downstream in the APCS and will probably exceed 10 in. at the inlet of the ID fan. Sealing around sampling probes in the areas of the baghouse, the scrubber and cooler/condenser will be especially important due to the high draft. Sample probes will be

Table 5-1. ALRC melter process monitoring summary.

Parameter	Units	Recording method Continuous data logger (automatic)	Manual	Frequency[a]
Melter				
Electrode phase to phase voltage	V		x	once/hr
Electrode phase to neutral voltage	V	x		C
Electrode current	A	x		C
Power factor	—	x		C
Active power	kW	x		C
Conductance factor	I^2/kW		x	once/hr
Material feedrate	lb/h	x	x	once/15 min.
Total material feed	lb/test		x	once/test
Energy efficiency	kWh/lb		x	once/hr
Cold top depth	in.		x	C, once/10 min.
Slag tap temperature, T_9	°C	x		C
Slag tap rate	lb/h		x	Every slag pot
Electrode stroke position	in.		x	once/15 min.
Bath temperature	°C		x	once/test
Slag viscosity (estimate)	---		x	30 minutes or during taps
Metal tap temperature	°C		x	During taps
Furnace static pressure	in. H_2O	x	x	C
Furnace hearth temperature, T_7	°C	x		C
Furnace upper inside wall T	°C	x		C
Furnace plenum temperature	°C	x		C
Furnace roof temperature	°C	x		C
Hearth shell temperature, T_8	°C	x		C
Electrode consumption	lb/test		x	1/test
Oxidizing air flowrate	scfm	x		C
Oxidizing air temperature	°C	x		C

Table 5-1. (continued).

Parameter	Units	Recording method: Continuous data logger (automatic)	Recording method: Manual	Frequency[a]
Air Pollution Control System				
Crossover gas temperature	°C	x		C
Thermal oxidizer (TO) inlet T	°C			
TO outlet temperature	°C	x	x	C
TO combustion air flowrate	scfm	x	x	C
TO combustion air temperature	°C	x		C
TO fuel flowrate	scfm		x	30 minutes
Spray dryer water flowrate	gpm	x	x	C
Spray dryer water temperature	°C	x		C
Spray dryer outlet temperature	°C	x		C
Quench air temperature	°C	x		C
Quench air pressure	°C	x		C
Quench air flowrate	scfm	x		C
Quench outlet temperature	°C	x		C
Quench outlet pressure	°C	x		C
Baghouse inlet temperature	°C	x		C
Baghouse inlet pressure	in. H_2O	x		C
Baghouse outlet temperature	°C	x		C
Baghouse outlet pressure	in. H_2O	x		C
Baghouse outlet flowrate	scfm	x		C
Scrubber liquor flowrate	gpm		x	once/30 min.
Scrubber liquor temperature	°C	x		C
Scrubber blowdown flowrate	gpm		x	once/30 min.
Scrubber blowdown temperature	°C	x		C
Scrubber liquor pH	-		x	once/30 min.
Scrubber outlet gas temperature	°C	x		C
Scrubber outlet gas pressure	in. H_2O	x		C
Condenser water flowrate	°C		x	once/30 min.

Table 5-1. (continued).

Parameter	Units	Recording method: Continuous data logger (automatic)	Recording method: Manual	Frequency[a]
Condenser outlet gas temperature	°C	x		C
Condenser outlet gas pressure	in. H_2O	x		C
Reheater power	kW		x	once/30 min.
Reheater outlet gas temperature	scfm		x	30 minutes
HEPA filter inlet gas temperature	°C	x		C
HEPA filter inlet gas pressure	°C	x		C
HEPA/carbon filter differential pressure P	in. H_2O	x		C
Stack gas temperature	°C	x		C
Stack gas flowrate	scfm	x		C
TO catch mass	lb/test		x	once/test
Cyclone catch mass	lb/test		x	once/test
Baghouse hopper catch mass	lb/test		x	once/test
Cooling Water Flowrates and Outlet Temperatures				
Inlet water flow	gpm,°C		x	once/30 min.
Cables, clamps, arms	gpm,°C		x	once/30 min.
Feed tubes	gpm,°C		x	once/30 min.
Furnace roof	gpm,°C		x	once/30 min.
Furnace shell	gpm,°C		x	once/30 min.
Cinder monkey	gpm,°C		x	once/30 min.
Exit duct	gpm,°C		x	once/30 min.

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[a] C = continuous, with 2-minute automatic printout

Table 5-2. Sample collection summary.

Feed mixture	Test objective	Process samples collected[a]			APCS samples collected[a,b]	
		Slag tap	Metal tap	APCS (3 locations)	MMT front half	MMT back half
RDF-0	RDF bottom ash demonstration	7	2	3	1	1
RDF-10A	RDF bottom ash w/asbestos surrogate	7	2	3	2	2
Nom-90	Stepwise increase of nominal waste mixture in soil	4		3		
Nom-80-1	Stepwise increase of nominal waste mixture in soil	4		3		
Nom-80-2	System performance evaluation	4	2	3	1	1
Nom-70	Stepwise increase of nominal waste mixture in soil	4	2	3		
Nom-60-1	Stepwise increase of nominal waste mixture in soil, lower power density and feedrate	4		3	1	1
Nom-60-2	Add solid oxidant in feed	4	2	3	1	1
Nom-60-3	Added air thru lance for oxidizing metal	4		3	2	2
Nom-60-4	Operate without cold top	4	2	3	2	2
Total samples		46	12	30	10	10

a. The actual number of samples may vary based on the actual operating time and amount of material processed in each test.

b. APCS samples = Solid samples collected from all collection points in system (particularly from the thermal oxidizer, cyclone, and baghouse).

Table 5-3. Process sample handling summary.

Process sample	Sample location	Sample size	Sample frequency	Sample handling
Slag product	Slag tap	Approx. 5 kg ladle sample	Mid-way through each pot, or when considered necessary via metal dip rod when not tapping	Crush each individual sample; split remaining sample by coning/quartering as needed to obtain analysis aliquots; archive remainder
Metal product	Metal tap (or from dip rod if not tapping)	Approx. 5 kg ladle sample	Mid-way through each pot, or when considered necessary via metal dip rod when not tapping	Not available
Thermal oxidizer catch	Thermal oxidizer hopper	Entire amount[a]	End of each test condition	Crush each individual sample as needed; split sample by coning/quartering as needed to obtain analysis aliquots; archive remainder
Cyclone catch	Cyclone	Entire amount[a]	End of each test condition	Crush each individual sample as needed; split sample by coning/quartering as needed to obtain analysis aliquots; archive remainder
Baghouse catch	Baghouse hopper	Entire amount[a]	End of each test condition	Crush each individual sample as needed; split sample by coning/quartering as needed to obtain analysis aliquots; archive remainder
Scrubber feedwater	House water supply	1 L	Once during test program	Archive
Scrubber caustic	House water supply	1 L	Once during test program	Archive
Scrubber blowdown	Scrubber blowdown	1 L	Once midway through each test condition	Analyze aliquots as needed; archive remainder

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a. The offgas system residues will be collected as completely as possible from the hoppers and traps in the system.

Table 5-4. Gaseous and particulate measurement and sampling procedures.

Sample location (port location)	Procedure	Reference	Sampling/measurement time	Sampling point matrix	Equipment	Comments
Sample ports upstream of baghouse	Gas temperature by suction pyrometer	EPRI CS-5552	20-60 minutes/traverse	Minimum 3-point traverse (far wall, near wall, centerline) and single-point	Combined and separate suction pyrometer and S-type pitot, and gas sampling probes in air or water-cooled sheaths.	Low gas velocities of around 1-10 f/s in furnace require sensitive manometer or pressure transducer, calibrated with pitot at low velocities. The gas sampling probes may require inertial phase separation to prevent plugging. Traversing and long-term sampling in furnace may be limited to quartz or alumina probes for safety.
	Gas velocity	EPA Method 2	Same as above	Same as above	Same as above	Same as above
	Offgas composition by specific EPA procedure	EPA 3A, 6C, 7E, 10, 25A	Same as above	Same as above	Same as above	Same as above with the added HCL air-dilution probe
	Offgas composition by gas chromatograph	MTI operating manual	up to 1 hr	Same as above	Same	Same as above, with additional gas scrubbing to remove acid gases, especially HCl. Samples will be collected into Tedlar bags for discrete injection and protection of GC
	Gaseous Cl_2	EPA 26 modified to include Cl_2 analysis				
	Particle size, particulate, and metals	EPA 201A (40 CFR 52, App. M) PM_{10} procedure	Approx. 1 hr	Per EPA Method 1 where possible	PM_{10} sampling train with cyclones	Isokinetic with the average gas velocity. SS probes will be used rather than glass probes for strength
	Fume slagging/ fouling potential	EPRI CS-5552	up to 1 hr	---	Water or air-cooled SS sampling probe	Relative measurement of fume tendency to adhere to probe
Sample ports downstream of baghouse	Gas velocity, temperature	EPA 1, 2	5-30 min	Per EPA Method 1	Sheathed probes as needed upstream of ID fan for sealing in port	Used separately from MMT probe only to verify installed continuous V and T probes
	Offgas composition	EPA 3A, 6C, 7E, 10, 25A, draft HCl procedure	up to 1 hr/traverse	Minimum 3 points for stratification check, then single-point	Same as above, but the HCl probe may be an air-dilution probe	

Table 5-4. (continued).

Sample location (port location)	Procedure	Reference	Sampling/measurement time	Sampling point matrix	Equipment	Comments
	Offgas composition by gas chromatograph	MTI operating manual	up to 1 hr	Same as above	Same as above	Sampling will be continuous at the stack, and using Tedlar bags for discrete injection and protection of GC at other sample locations. Additional gas scrubbing to remove acid gases, especially HCl, will be required at sample locations upstream of the wet scrubber.
	Total particulate and metals	EPA draft Method 29 (MMT)	2-4 hr minimum	Per EPA MMT		Glass or quartz-lined probe

sealed during insertion, sample collection, and removal using a sealing gland around the probe and ball valves on the sample ports similar to the schematic as shown in Figure 5-1.

There may be some cases when using a port momentarily without a tight seal may be necessary. Such cases may include furnace bath depth probing, slag or metal sampling from the bath, bath temperature measurements, and fouling probe removal. At such times the furnace draft will be adjusted to ensure that there will not be gaseous effluents from the furnace through the port.

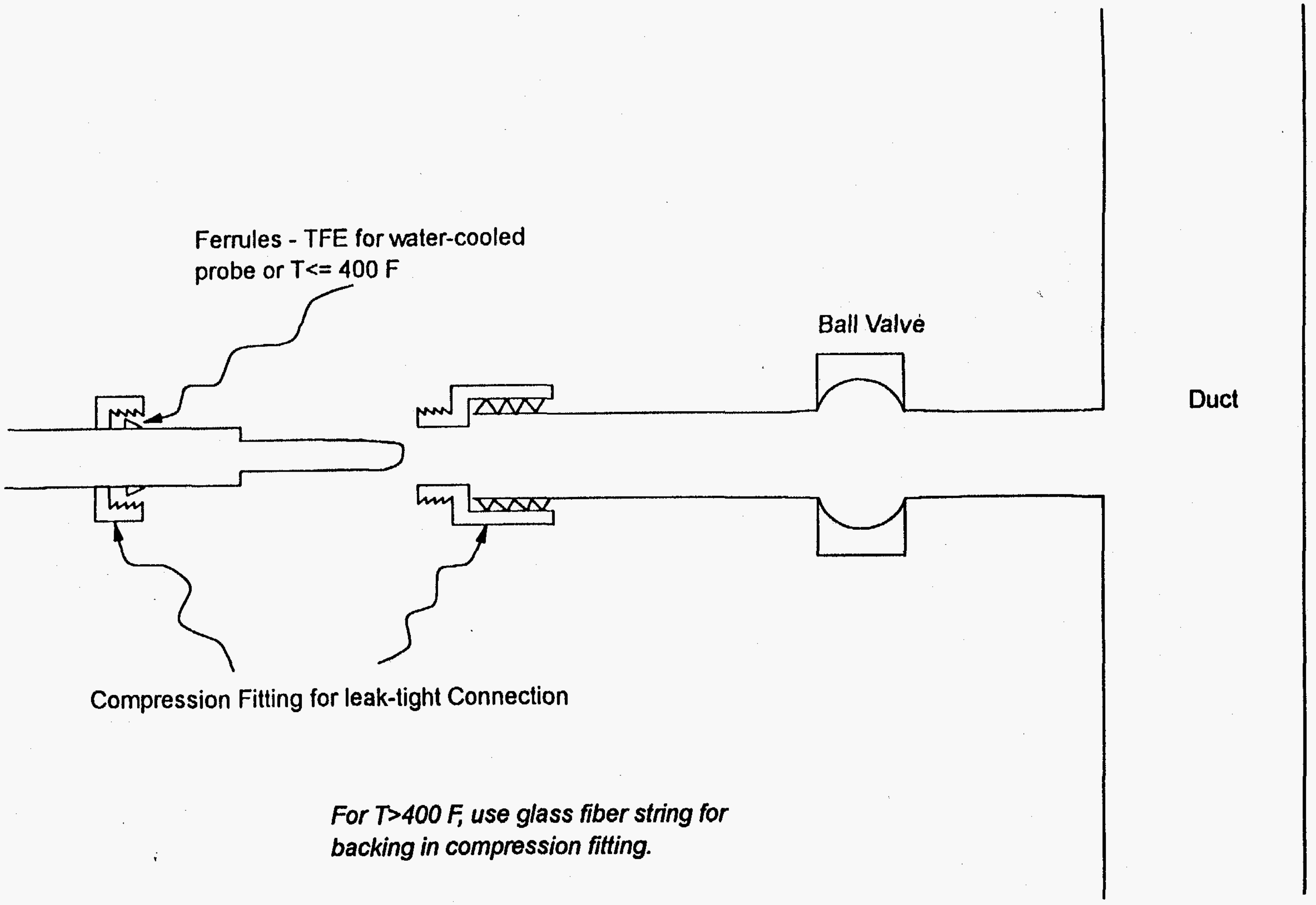
5.3.1 High-temperature Measurements

Accurate gas temperature measurements made in the high temperature furnace plenum, thermal oxidizer inlet and thermal oxidizer outlet locations will require the use of a radiation-shielded suction pyrometer, also called a high velocity temperature (HVT) measuring probe. The general procedure and typical equipment used in these types of measurements is described in EPRI CS-5552.[11] A schematic of a typical water-cooled suction pyrometer probe is shown in Figure 5-2. The thermocouple tip is shielded from thermal radiation by a metal or ceramic sheath. The gas is drawn through the probe at a sufficiently high velocity so that the convection heat transfer to the thermocouple (TC) is far greater than radiative heat transfer from the sheath or open end of the sheath, and also far greater than conductive heat transfer from the TC to the water-cooled probe. The potential errors from radiative and conductive heat transfer are minimized relative to the convective heat transfer from the gas, enabling the TC to more accurately sense the actual gas temperature.

Velocity measurements in the high temperature regions will be performed using the same procedures specified for velocity measurements in the cooler regions, per EPA Method 2. The high levels of particulate upstream of the baghouse will cause increased plugging that must be monitored and may require frequent removal, especially if the particulate is at or above its melting temperature range. The pitot should be contained in a cooled sheath for sealing in the sample ports and for cooling of the pitot to minimize adhesion of particulate.

Gas composition measurements will require the use of a phase discrimination probe or an in-line cyclone to separate most of the particulate from the sample gas and reduce filter plugging in the sampling system. Phase discrimination (inertial separation of particulate from the sample gas) can be achieved by properly designing a combined suction pyrometer and gas sampling system, so the sample gas for the gas analyzers is a small fraction of the total suction pyrometer flow. An example of such a system is shown in Figure 5-3.

Slagging and fouling in the furnace plenum, thermal oxidizer, and connecting ductwork can occasionally be a significant problem. While fouling was not a problem in the APCS for the FY-93 BWID tests,[12] there was severe plugging of the furnace outlet duct during the earlier ASME municipal incinerator ash tests. Higher expected offgas temperatures for the planned Phase 2 tests, together with potentially large amounts of entrained soil dust and fume, may result in buildup of accretions in the planned tests under some conditions. The potential for accretions buildup will be evaluated using a stainless steel, cooled fouling probe inserted in the offgas. Using a thermocouple welded to the probe wall, the probe temperature may be set within an approximate range. Accretion buildup on the probe can be monitored over time and compared to other probe and gas temperatures and furnace operating conditions.



For T>400 F, use glass fiber string for backing in compression fitting.

Figure 5-1. Seal for leak-tight ports during sampling.

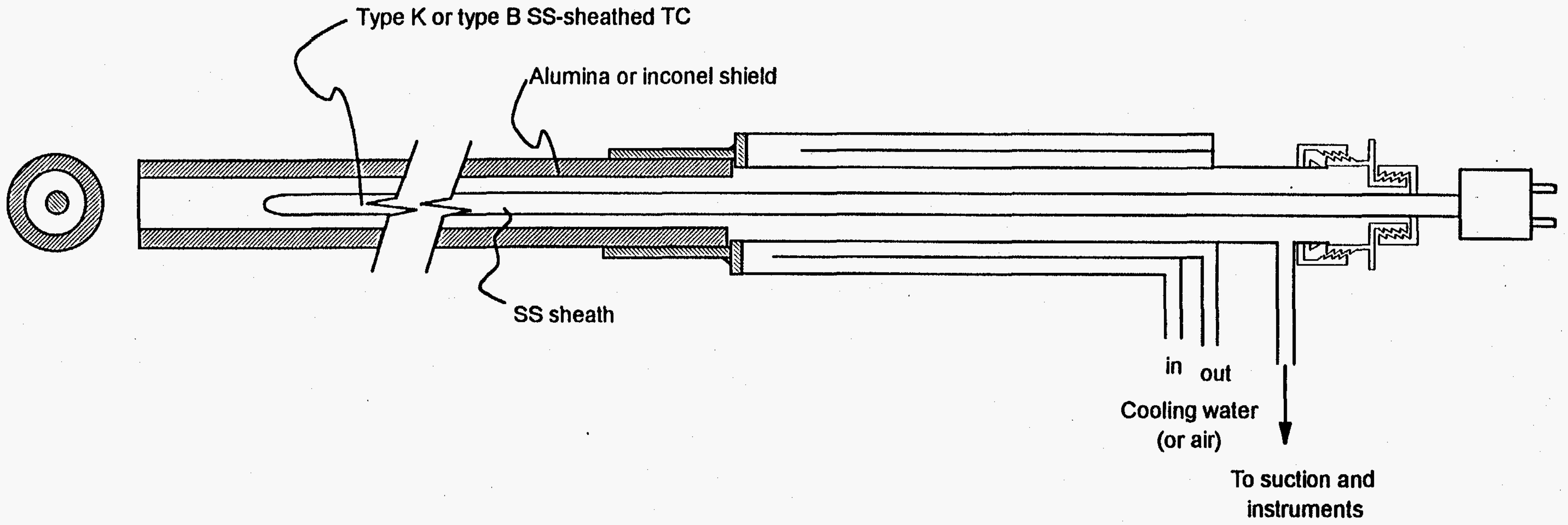
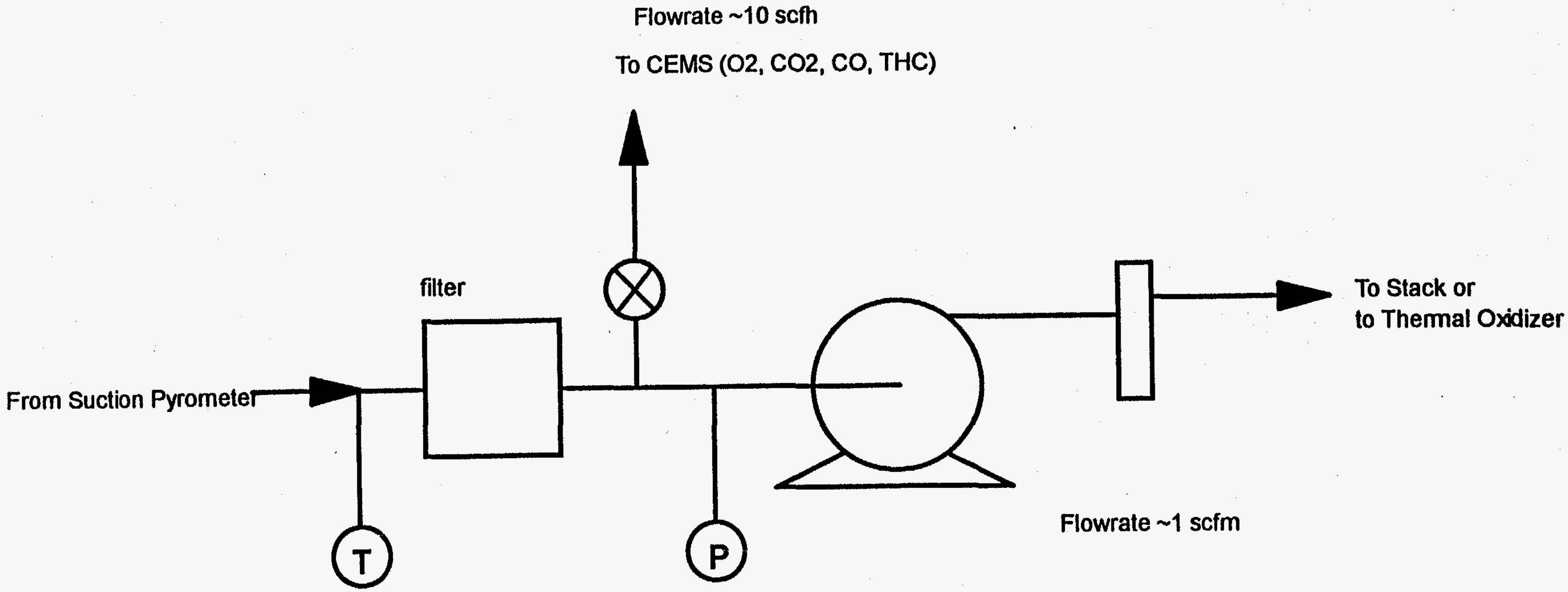


Figure 5-2. Schematic of typical water-cooled suction pyrometer probe.



suction.pre

Figure 5-3. CEMS bypass for on the pyrometer suction system.

Particle size, particulate, and metals will be measured in the high temperature regions using a modified version of the PM_{10} sampling train. In this procedure, a series of one to three cyclones located on the end of the sample probe are used to separate three different particle size fractions. Sampling at a high rate will reduce the particle size of the fractions so that the particles exiting the last cyclone will be less than 10 µ. The sample gas is passed through a filter, and an impinger set containing MMT absorbing solutions, to cool and capture any metals and particulate not captured in the upstream cyclones and the filter. The particulate captured in the cyclones will be mainly entrained dust, while the particulate and gas exiting the third cyclone (and captured in the filter and the impingers) will be enriched in condensed fume from materials volatilized from the melt.

The modified PM_{10} procedure may have operational difficulties such as buildup of accretions in the cyclones, or damage to the probe and cyclone materials from high temperatures. If this procedure is successful, however, it can provide better differentiation between volatilized materials and entrained feed dust, because separation of the entrained dust particles and the volatilized materials will be done before cooling and condensation of the volatilized materials in the APCS.

If the modified PM_{10} procedure cannot be successfully used due to the sampling conditions, then one or all of the upfront cyclones will be removed or placed at the back end of the sample probe. This will decrease the ability to differentiate between entrained feed dust and volatilized material.

5.3.2 Continuous Gaseous Emissions Monitoring Procedures

The continuous gaseous emissions monitoring will be performed according to Environmental Protection Agency (EPA) continuous monitoring methods. To best characterize the melter emissions and continuously monitor variations in melter performance, sampling will be done in the furnace, at the furnace outlet and at the cooler outlet (upstream of the baghouse) at selected times during the demonstration tests. As discussed in Section 5.3.1, special sampling techniques such as the use of phase discrimination probes and water or air cooling may be required for continuous gas sampling in the high-temperature, particulate laden regions upstream of the spray cooler.

Sample gas will be extracted using a stainless steel sample probe that will be heated or cooled depending on the sample location. Sample collection at the melter outlet may require cooling the sample probe. The sample gas will be filtered and cooled to remove moisture before being introduced to the gas analyzers. Flow to each instrument will be controlled using a sample gas manifold with individual control valves and flowmeters for each instrument. All fittings and sample lines that contact the sample will be constructed of either stainless steel, teflon, or other materials that will not react with the sample gas. Leak checks, bias, residence time, interference, and sampling procedures will be conducted according the EPA applicable reference procedures.

For the purposes of this test program, some variations from the EPA procedures may be utilized that will not significantly compromise the quality of the results. Possible variations include (a) use of less stringent ± 2% calibration gases rather than EPA protocol gases and (b) variations in sample periods or averaging so that sample collection can coincide with melter operating periods.

When continuous monitoring is not necessary, grab samples of offgases at selected locations will be collected for subsequent injection into the CEMS instruments. This will significantly reduce the need for replicate CEM systems and provide more flexibility for measuring gas concentrations at various furnace and APCS locations. Grab samples will be collected in reusable Tedlar bags.

5.3.3 Gas Chromatography Procedures

Speciated analysis of some gases will be done using a Microtechnologies Inc. (MTI) Q300L gas chromatograph (GC), with three capillary columns and an electrical conductivity detector. Manufacturer information for this GC is as follows:

Column	Carrier gas	Can detect:
Molecular sieve 10 m long	He or Ar	He (when Ar is carrier gas), H_2 (when Ar is carrier gas), O_2, N_2, CO (when He is carrier gas), C_1
Pora Plot Q, 4 m long	He or Ar	CO_2, C_2-C_4
OV-1, 4 m long	He or Ar	CCl_4, TCE, several other halogenated hydrocarbons and volatile organic compounds (VOCs)

Hydrogen can only be detected when Ar (not He) is the carrier gas because H_2 and He have similar retention times on the molecular sieve column. Likewise, CO can only be detected using He (not Ar) due to similar retention times for CO and Ar. NO, NO_2, HCl, Cl_2, and SO_2 are too reactive to obtain quantitative measurements except for very high levels of NO and SO_2. It may be possible to detect aldehydes on the OV-1 column. High levels of acid gases, especially HCl but also SO_2 and NO_2, can rapidly damage components of the GC, and so must be scrubbed out of the gas for all of the sample locations except downstream of the wet scrubber. The sample gas at all locations must be filtered and cooled to below ambient temperature to prevent particulate or water droplets in the GC injector, even though there is a backup Genie filter in the GC inlet. Particulate or water droplets in the injector will invalidate results and may damage the GC.

5.3.4 Metals and Particulate Sampling Procedures

Gaseous and particulate metals emissions in the offgas will be determined using the EPA MMT (Draft EPA Method 29, October 29, 1990). This procedure is modeled after the EPA Method 5 procedure (40 CFR 60, Appendix A, 1990) for determining total particulate emissions from stationary sources. Using the Draft Method 29 procedure, an offgas sample is collected isokinetically from the offgas stream to obtain the most representative gaseous and entrained particulate sample. Using a heated, glass-lined sample probe with a sharp-edged glass nozzle, the duct is traversed during sample collection to minimize the effects of velocity and concentration stratification. The sample is passed through a filter heated to 250 ±25°F, which is used to capture particulate or aerosol material at that temperature. The filtered sample is then passed through a series of glass impingers that contain absorbing solution for capturing metals and other materials. The last impinger contains silica gel for complete drying of the gas sample. The impingers are maintained in an ice bath so that the gas sample is rapidly cooled, and the temperature of gas leaving the last (silica gel) impinger is 68°F or less. The volume and sample rate of filtered, dried sample gas is controlled and monitored using a calibrated dry gas meter, sharp-edged orifice, and sample pump.

Following sample collection, the sample is quantitatively recovered from the inside of the nozzle and sample probe, filter housing, connecting glassware, and impingers. The front half of the sample train (from the probe nozzle to the filter) will be gravimetrically analyzed to determine the solid particulate levels in the offgas. The front and back halves (downstream of the filter, including the impinger catch) will be analyzed for the target metals and surrogate radionuclides by ion-coupled argon plasma spectroscopy (ICAP) or by graphite furnace atomic absorption spectroscopy (GFAAS). If mercury is one of the target metals, cold-vapor atomic absorption spectroscopy (CVAAS) is used.

Chemical reagents of the minimum purity and specifications identified in the Draft EPA Method 29 procedures will be used for all sampling and analysis activities. All materials that contact the sample will be glass or other nonmetallic, noncontaminating material. All connections will be leak free, ground glass fittings, or other noncontaminating materials. All glassware and sample containers will be carefully cleaned using the specified metals-free reagents and dried in a dust-free environment after cleaning.

All sampling and analysis procedures will be performed in accordance with the specifications in the draft method. These procedures include sample train preparation, calibration, reagent preparation, leak checks, train operation, and sample recovery, preparation, and analysis. QA/quality control (QC) procedures will also be performed in accordance with requirements specified in the EPA Draft Method 29, EPA 6010, or EPA 7000-series procedures.

Variations from the standard Draft EPA Method 29 procedure may include (a) elimination of the impingers that contain absorbing solution (acidified potassium permanganate) for capturing mercury, (b) elimination of mercury analysis by CVAAS, (c) inclusion of gravimetric analysis of the train front half for solid particulate determination, (d) combination of the train front and back half metals analysis for reduced analysis cost, (e) use of a short stainless steel probe instead of a glass probe for combination with the in-stack PM_{10} particle sizing procedure, and (f) single-point sampling (MMT-SP) when deemed necessary to expedite sample collection. Any other modifications to the sampling and analysis procedures that are necessary to meet the project objectives will be made to ensure data accuracy and representativeness of the operating conditions during the test periods. All changes will be carefully documented and justified with all available support information.

5.3.5 Offgas Sampling Team

The offgas and particulate sample collection and analysis performed during the onsite test periods includes sample collection and measurements at up to several locations in the furnace and APCS. The sampling conditions upstream of the spray cooler will be most severe, being in the proximity of high-temperature equipment, near the gas burners and the furnace power system, and having high temperature and particulate laden offgas. Sampling downstream of the spray cooler will also require making exacting measurements of offgas and particulate. These activities will require up to three experienced personnel. The expected duties for these personnel are described below.

Person	Activity
1	Sample team leader, QA overview, sampling and process coordination, and gaseous and metals train data analysis—N.R. Soelberg of LITCO
2,3	Sample collection and measurements upstream of the spray cooler, including suction pyrometer temperature measurements, velocity measurements, CEMS sampling, and PM_{10} sampling for selected test conditions—subcontracted test personnel
4,5	Sample collection and measurements downstream of the spray cooler, including temperature and velocity measurements, CEMS sampling, and MMT sampling for selected test conditions—subcontracted test personnel
6	Continuous monitoring and CEMS data analysis—subcontracted test personnel
7	GC operations and analysis—Del Baker of USBM

The above specified personnel will be required for test conditions when particulate sampling is performed. Fewer personnel will be required for test conditions when only temperature, velocity, and gaseous measurements are necessary.

The recommended minimum amounts and types of test equipment for the fume and offgas sampling includes

- Suction pyrometer, velocity and CEMS measurements upstream of the spray cooler—Water-cooled, sheathed probe and sampling system that includes the suction pyrometer, an S-type pitot, and CEMS bypass. The CEMS bypass system should have the necessary filtration and sample conditioning equipment to tolerate the high-temperature, particulate-laden offgas and protect the downstream sample equipment and instrumentation during continuous operation.

- Separate suction pyrometer, pitot and gas sampling probes, sheathed for sealing in sample ports, for separate measurements and sampling as needed

- PM_{10} sample collection—At least two control boxes (one with a spare), two and two each umbilicals, heated filter boxes, impinger boxes, sample probes with cyclones, nozzles, and miscellaneous spare parts such as fittings, tubing, thermocouples, and glassware.

- Velocity and temperature measurements downstream of spray cooler—uncooled, sheathed TC and pitot for leak-tight sampling through ports

- CEMS sampling downstream of spray cooler—uncooled, filter-tipped probes for both continuous and Tedlar bag sampling. The Tedlar bag sampling system should include a separate pump in a leak-tight, portable sampling apparatus.

- CEMS instrumentation—one complete system, with the sampling system valved to be able to readily switch between continuous sampling through sample lines upstream or downstream of the spray cooler, or to sample from Tedlar bags. The instrumentation should include (a) the required analyzers in a temperature-controlled environment, (b) a conditioning system, (c) zero, mid-range and high-range calibration gases (certified ± 2% or better), (d) chart recorder, and (e) optional computer data acquisition system.

- MMT sample collection—At least two each (one with a spare) control boxes, umbilicals, heated filter boxes, impinger boxes, heated, glass-lined sample probes with nozzles, glassware, filter housings, and miscellaneous spare parts such as fittings, tubing, and thermocouples.

- GC instrumentation—MTI GC with carrier gases and calibration gases. The GC inlet should be valved to continuously receive conditioned gas from the stack sample location, and also be fitted with a port for injecting gas from Tedlar bags.

- Portable Tedlar bag sampling system—complete with an uncooled sample probe, a filter, a gas cooler and scrubber, and a sample pump, with fittings for easy Tedlar bag handling.

6. DOCUMENT CONTROL

Control of project documents, test data, and project files is important for this cooperative program, which is sponsored and performed by different entities. The USBM document control system is being used for test records and system configuration control. Where applicable, compliance with the LITCO standards for BWID issued documents[13] will be followed. Document generation and control procedures will provide necessary recordkeeping documentation for BWID.

6.1 Data Documentation, Control, and Storage

Document control for test data will begin with the raw data sheets and sample analysis data. These raw data records will be maintained in project files at the USBM by those generating the raw data. The process operating, monitoring, and process sample collection data will be documented and controlled by the USBM. Hard copies such as the hand-recorded data logs will be filed by the USBM lead personnel, while electronic copies of the data logger output will be filed on 3.5-in. disks and on the computer hard-drive. Copies of both the hard-copies and electronic files will also be provided to LITCO personnel.

The offgas sampling and analysis data will be controlled by LITCO, but copies of both electronic files and hard copies will also be maintained by the subcontracted testing firm. Engineering drawings and configuration control for the melter test system and facility will be controlled by USBM, but copies will be provided to LITCO.

6.2 Test Plan Change Control

This test plan has been prepared by LITCO with contributions from USBM. The test plan is the primary test project guidance document for the Phase 2 test program. The test plan is a controlled document of LITCO. The USBM will generate specific test procedures as needed within the logical framework of this test plan.

Changes may be made to the test plan before or during the demonstration test by the cognizant test personnel. Any necessary changes may be made before the demonstration tests by agreement between the LITCO Principal Investigators and the ALRC Melter Facility Project Manager. Changes made during the demonstration tests may be made by responsible onsite LITCO and ALRC test supervisory personnel. Changes will only be made using sound engineering judgement to ensure the highest possible data quality within available funding and safe operation, in the event of circumstances that cause deviations from the test plan. While it is planned to complete the full scope of test conditions, sampling and analysis described in this test plan, there are several potential circumstances that may dictate changes to the test plan prior to or during the demonstration tests. These circumstances include (a) insufficient BWID funding, (b) information provided by other programs such as the Idaho Waste Processing Facility team, and (c) results of the planned shakedown tests. Any changes will be documented in test logs.

6.3 Document Control for Other Documents

Other documents will include the (a) quick look field data test report summarizing activities of the demonstration test, and (b) the evaluation report prepared by ALRC and LITCO. All project notes, correspondence, and other project detailed files will become part of the project files controlled by LITCO and USBM.

7. ANALYTICAL METHODS

The sample analysis matrix for the demonstration test samples is shown in Table 7-1. All of the sample analysis will be conducted at the ALRC or another experienced laboratory, selected for those few analyses the ALRC laboratory is not equipped to perform. The most critical analyses are summarized in Table 7-2. These analyses include those performed for the process samples and offgas samples. Standard EPA-promulgated methods are used where possible. Some analytes, such as the TRU surrogates, are not specifically included in the cited methods. However, the most applicable methods will be applied where possible to achieve the most accurate results, and the laboratory will base procedures on results obtained from similar analyses on similar samples performed in the Phase 1 test program. QA activities specified by these methods typically include spikes, duplicates, and splits. However, analysis standards are not readily available for some elements, so such QA activities will be performed only where standards are available.

Table 7-1. Sample analysis matrix.

			Sample Analyses						
Test no.	Test objective	Sample type	Full elemental[a]	Slag formers[b]	Partial elemental[c]	Fe^{+2}/Fe^{+3}	XRD[d]	Leach-ability[e]	SEM/ Micro-probe[f]
RDF-0	RDF bottom ash demonstration	Slag	2 (last 2 pots)	5		2 (last 2 pots)	2 (last 2 pots)	2 (last 2 pots)	
		Metal	1						
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		Scrubber BD			1				
		MMT FH			1				
		MMT BH			1				
RDF-10A	RDF bottom ash w/asbestos surrogate	Slag	2	5		2	2	2	
		Metal	1						
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		Scrubber BD			1				
		MMT FH			2				
		MMT BH			2				
Nom-90	Stepwise increase of nominal waste mixture in soil	Slag	2	5					
		TO catch	1						
		Cyclone catch	1						
		BH catch	1						
Nom-80-1	Stepwise increase of nominal waste mixture in soil (Same sampling and analysis matrix that Nom-90 has)	Slag	2	5					
		TO catch	1						
		Cyclone catch	1						
		BH catch	1						

Table 7-1. (continued).

			Sample Analyses						
Test no.	Test objective	Sample type	Full elemental[a]	Slag formers[b]	Partial elemental[c]	Fe^{+2}/Fe^{+3}	XRD[d]	Leach-ability[e]	SEM/ Micro-probe[f]
Nom-80-2	System performance evaluation	Slag	2	5		2	2	2	
		Metal	1						
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		MMT FH			1				
		MMT BH			1				
		Scrubber BD			1				
Nom-70	Stepwise increase of nominal waste mixture in soil (Same sampling and analysis matrix that Nom-90-1 has)	Slag	2	5					
		Metal	1						
		TO catch	1						
		Cyclone catch	1						
		BH catch	1						
Nom-60-1	Stepwise increase of nominal waste, lower power density and feedrate	Slag	2	5		2	2	2	
		Metal							
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		MMT FH			1				
		MMT BH			1				
		Scrubber BD			1				
Nom-60-2	Added solid oxidant in feed	Slag	2	5		2	2	2	
		Metal	1						
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		MMT FH			1				
		MMT BH			1				
		Scrubber BD			1				

Table 7-1. (continued).

			Sample Analyses						
Test no.	Test objective	Sample type	Full elemental[a]	Slag formers[b]	Partial elemental[c]	Fe^{+2}/Fe^{+3}	XRD[d]	Leach-ability[e]	SEM/ Micro-probe[f]
Nom-60-3	Added air thru lance for oxidizing metal	Slag	2	5		2	2	2	
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		MMT FH			2				
		MMT BH			2				
		Scrubber BD			1				
Nom-60-4	Operate without cold top	Slag	2	5		2	2	2	
		Metal	1						
		TO catch	1						1
		Cyclone catch	1						1
		BH catch	1						1
		APCS comp				1		1	
		Scrubber BD			1				
		MMT FH			2				
		MMT BH			2				
Total Samples			54	50	27	19	14	21	21

a. Full elemental—full set metals (18 metals—Al, As, Ba, Ca, Ce, Cr, Cs, Cu, Fe, K, Mg, Na, Ni, Pb, Si, Ti, Zn, and Zr) plus P, S, C, and Cl.

b. Slag formers include Al, Ca, Fe, K, Mg, Na, and Si.

c. Partial elemental (15 metals)—Al, As, Ba, Ca, Ce, Cr, Cs, Cu, K, Mg, Na, Ni, Pb, Si, Zn.d. XRD—X-ray diffraction.

d. XRD—x-ray diffraction.

e. Leachability tests include both toxicity characteristic leachability procedure (TCLP) and PCT-1.

f. SEM—Scanning electron micrograph, and includes determination of particle size distribution. Other potential alternative analyses include x-ray fluorescence and optical microscopy.

Table 7-2. Sample analysis procedures.

Applicable samples/materials	Analytes	Method	Analysis procedure	Detection limits	Handling and preparation	Method highlights
All process samples, including slag samples, metal samples, and APCS solid samples (catches from the thermal oxidizer, spray dryer, and baghouse)	Full set metals[a]	SW846 6010 or 7000 Series (Hg by 7470)	ICAP[b], GFAAS[c], or CVAAS[d]	Varies, generally 1-10 mg/kg	100 mg-1 g sample digestions with HF, HCl, HNO_3 per USBM ALRC procedure[e]	ICAP for most analytes. Cs by GFAAS using standard additions, no spike. Hg by CVAAS. Following ICAP analysis, data will be evaluated to determine applicability of GFAAS for some analytes to improve detection limits
	P	AOAC method[f] total phosphorous determination	Digestion/ precipitation/ gravimetry	Estimate mg/kg	Digest with $HF/HClO_4$ nitrate	AOAC method will be modified slightly per USBM ALRC experience
	S	LECO CS144	LECO CS144 gas analyzer	5 ppm by wt.	---	High-temperature oxidation and infrared gas analysis
	Total C	LECO CS144	LECO CS 144 gas analyzer	5 ppm by wt.	---	High-temperature oxidation and infrared gas analysis
	Cl	USBM ALRC analysis	Ion chromatography	2 mg/kg	Digest with H_2SO_4	>24-h digestions, followed by IC analysis
	PCT-1 leachability	PCT-1	Not available	Not available	Not available	Basic digestion followed by analysis of liquor
	TCLP leachability	TCLP[g], 40 CFR 261, App. II	Size-reduce, acid extraction, SW846 analysis	Varies, generally 1-10 ng/mL	Grind to size <9.5 mm	Mild acid digestion followed by analysis of liquor by SWS46 methods
	Total Fe	USBM IC 9240 Total Ion Analysis[h]	Oxidation by potassium dichromate/dichromate titration	1-10 mg/kg	---	Better results than GFAAS when iron level >2 wt%
	Fe^{+2}/Fe^{+3}	USBM IC 9240 Ferrous Iron Analysis[h]	Ferrous iron titration	0.1-1 wt%	Digest using $vanadium^{+5}/H_2SO_4/HF$	Wet chemistry technique
	Si	USBM IC 9240 Gravimetric Silica Determination[h]	Gravimetric dehydration	1-10 mg/kg	---	Silicic acid is dehydrated using sulfuric and perchloric acids, HF addition, SiF_4 volatilization, and gravimetric analysis
	Physical characteristics, particle size	Scanning electron microscope	---	---	---	Subjective analysis by experienced SEM technician
	Chemical composition of specific structures	Microprobe	---	0.1 wt%	---	Subjective analysis by experienced SEM technician

Table 7-2. (continued).

Applicable samples/materials	Analytes	Method	Analysis procedure	Detection limits	Handling and preparation	Method highlights
	Crystalline structures	X-ray diffraction	---	3-5 wt%	---	
Process material (feed barrels, slag pots, baghouse barrels, electrode weights, etc)	Weight	Magna-View Floor Scale (Howe Richardson Scale Co.)	Gravimetric	2 lb graduations; 0.00 % calibrated error		
APCS catches	Weight	Fairbanks-Morse Springless Scale	Gravimetric	2 oz. graduations; 0.08 oz/lb calibrated error	—	Quantitative determination of all of the fume deposited material recovered
EPA 29 samples (probe acetone and acid catches, filter catches, and impinger catches)	Partial set metals[i]	EPA Draft Method 29 (SW846 6010 or 7000 Series, Hg by 7470)	ICAP, GFAAS, or CVAAS	Varies, generally 1-10 ng/mL	EPA Method 29-specified procedures	Metals analysis is done following gravimetric analysis on the probe acetone catches and filter catches. ICAP for most analytes. Cs by GFAAS using standard additions, no spike. Following ICAP analysis, data will be evaluated to determine applicability of GFAAS for some analytes to improve detection limits
EPA 29 samples (probe acetone catches and filter catches)	Weight	EPA Method 5	Gravimetric	Per EPA Method 5	Per EPA Method 5	Following gravimetric analysis, recombine with acid probe catch and impinger catch for metals analysis

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a. Full set metals (18 metals)—Al, As, Ba, Ca, Ce, Cr, Cs, Cu, Fe, K, Mg, Na, Ni, Pb, Si, Ti, Zn, and Zr.

b. ICAP—Ion-coupled argon plasma spectroscopy; using 1-g sample in 100 mL digestion solution for process samples.

c. GFAAS—Graphite furnace atomic absorption spectroscopy, using 200 mg sample in HNO_3 HF solution for process samples.

d. CVAAS—Cold vapor atomic absorption spectroscopy.

e. All vitrified samples will be digested using the USBM ALRC "Method for Dissolution of Vitrified Samples," August 19, 1992.

f. *Official Methods of Analysis of the Association of Official Agricultural Chemists*, 10th Edition, 1965, pages 11-13.

g. TCLP—Toxicity characteristic leachability procedure.

h. D. A. Baker and J. W. Sigle, "Methods for the Analysis of Mineral Chromites and Ferrochrome Slag," Bureau of Mines Information Circular, IC 9240, 1990.

i. Partial Set Metals (15 metals)—Al, As, Ba, Ca, Ce, Cr, Cs, Cu, K, Mg, Na, Ni, Pb, Si, Zn.

8. DATA REDUCTION, VALIDATION, AND VERIFICATION

Test data will be collected during this program to document and interpret the melter operation and meet the objectives. Data gathered during this program will include

- Melter system process data, including recorded DAS output and hand-recorded data sheets
- Records and results of all collected samples
- Offgas sampling and analysis data from the stack sampling subcontractor, including CEMS data and manual measurements and sampling data.

As much data as possible will be reduced and validated at the time of the field test, while the test team is still onsite. The critical advantage to this approach is that if deficiencies are found, then they may be more easily remedied while still onsite. Data reduction performed onsite will include

- Global mass balances of feed material and additives, slag, metal, APCS solids, and furnace inventory
- Offgas velocity, flowrate, and gas compositions
- Particulate and metals isokinetic sampling rates
- Melter process parameters, such as averages and ranges of feedrates, power levels, and tapping rates
- Global mass balance and furnace inventory calculations, including cumulative feed input, slag and metal tapping, and APCS solids collection
- Calculate isokinetic ratios for sampling trains.

Much of the data, however, cannot be generated or validated until well after completion of the field test program. This includes essentially all of the sample analytical results. Results of the offgas particulate and metals samples and process samples will be compiled, reduced, and evaluated promptly following completion of the laboratory analysis, while the samples are still available for reanalysis if needed. Data validation and verification steps will include checking the calculations, data entries, results, and flagging questionable data.

8.1 Data Reduction Scheme

Data will be recorded manually on data sheets and electronically in computer files and on stripcharts and other types of recorders. Data will be reduced and analyzed using hand-held calculator programs, computer spreadsheets, and other computer programs.

Data reduction for the offgas sampling and analysis will be conducted according to the reference test procedures (see Section 3). Data reduction for the process data will be conducted according to correct engineering principles and using verified calculations. Data reduction activities performed following the receipt of sample analysis results includes

- Entry of analytical results in spreadsheets for the manual sample trains for calculating particulate and metals concentrations and emission rates
- Entry of analytical results in spreadsheets for the process samples for calculating total instantaneous and average compositions and toxicity characteristic leachability procedure (TCLP) results
- Mass and energy balance closure spreadsheet calculations
- Volatile metals, particulate, and TRU surrogate partitioning determinations
- Comparison and interpretation of partitioning results and properties of the slag and metal melt phases to melter operating conditions and offgas conditions.

8.2 Data Validation

The test data will be validated, where possible, while the test team is still onsite so that corrective actions can be made more readily if necessary. Data collected on manually completed data sheets will be reviewed by the LITCO test director. Data that will be used in calculations will be entered into the appropriate spreadsheets, while informational data will be archived in test data notebooks. These notebooks are 3-ring binder compilations of all raw and reduced data. The LITCO Test Director or designee will control these notebooks. Stripchart recorder output and hard copies of electronic data files will be similarly reviewed by the data collectors and LITCO test director for completeness and accuracy. Applicable stripchart and electronic data will be entered into spreadsheet calculations, while the stripcharts, electronic files, and hard copies are filed in the test data records.

Data validation for the offgas sampling and analysis will be performed according to the specifications in the test procedures referenced in Section 5 and analytical procedures in Section 7. Data validation for the process monitoring data will be performed according to applicable QA activities such as determination of accuracy, precision, and completeness. Applicable QA activities include comparison of redundant or similar measurements, duplicate measurements for the same process instrument on different test days, calibrations, and calculations. Data validation for the process sample analytical results will be performed according to the analytical procedures referenced in Section 7.

The CEMS data will be recorded in 1 to 2-minute intervals. This data will be read into spreadsheets for data reduction and analysis. The following analysis will be performed using these spreadsheets:

- Identification of periods of invalid data
- Identification of calibration periods and zero, mid-span, and high-span values

- Identification of bias checks and values
- Identification of interference checks and values
- Bias, linearity, interference, zero drift, and span drift calculations
- Flagging of bias, linearity, interference, or drift calculations that exceed limits
- Calculation of 1 or 2-minute values corrected for interference and drift
- Calculation of average values during the entire test period and during each of the runs
- Calculation of maxima, minima, and standard deviations for the test period.

The linearity and bias calculations will be done according to procedures described in Section 5.

8.3 Data Validation Responsibilities

Data validation will be the ultimate responsibility of the test directors but can be performed by a qualified designee. Before submittal of the test data to the test director or designee, however, each individual data collector will be responsible for validating the collected data based on available criteria such as completeness, comparability to other previous measurements, process conditions, and conditions of the analytical equipment. For example, the offgas sampling data will first be validated by the sample train operator based on judgement of sample representativeness; cleanliness and maintenance of sampling equipment; adherence to approved, written sample collection procedures; and completeness of field data sheets. Further validation will be based on (a) process conditions during sampling or testing, (b) consistency with expected other results, and (c) adherence to prescribed QC procedures and control limits.

8.4 Acceptance Criteria for Test Data

Data validation and verification will be conducted, where possible, by comparing the results of QA and data validation activities to selected acceptance criteria and control limits. Acceptance criteria specified in the test and analytical procedures referenced in Sections 5 and 7 will be used. Tables 8-1 through 8-3 summarize the most important acceptance criteria for the offgas monitoring sampling activities. The acceptance criteria for the laboratory analyses are specified in the laboratory procedures referenced in Section 5. Data quality objectives for test data are discussed in Section 9.

Table 8-1. Offgas equipment calibrations.

Apparatus	Acceptance limits	Calibration frequency	Corrective action
Sampling nozzle	Maximum dev. ≤0.002 in. from average diameter	Before test	Return to glass blower for better rounding/grinding
Thermocouples (TC)	Impinger TC: ±2°F Gas meter TC: ±5.4°F Stack TC: ±1.5% Abs.	Calibrate each against mercury in-glass thermometer at a single point near operating range; for stack TCs, calibrate at 3 points	Repair to meet specifications or do not use, or plot curves and correct for ranges outside acceptable limits
Dry gas meters	$0.98 \leq Y_{m,i}/Y_{m,f} \leq 1.05$	Calibrate initially and when post-test check Y_m exceeds $Y_m \pm 0.05$	Adjust, determine a correction factor, or replace
CEMS calibration drift	SO_2, NO_x: ±2.5% full scale (FS) O_2, CO_2: ±0.5% CO: ±5% of FS for 6 out of 7 days Others: ±10% of FS	At least daily	Calibrate more frequently or make instrument adjustments
Barometer	±0.1-in. Hg of mercury-in-glass barometer	Before and after each field test	Adjust or make correction chart
Installed process TCs	±1.5% Abs.	Before and after each test campaign, and whenever results appear questionable	Perform maintenance on TC and connecting wire, or replace TC
Installed pressure indicators and transducers	±5% Abs.	Before and after each test campaign, and whenever results appear questionable	Perform maintenance, adjust, determine correction factor, or replace
Installed pitots	Meets dimensional requirements in 40 CFR 60 App. A, Method 2	Before and after each test campaign, and whenever results appear questionable	Inspect, clean, reshape, or replace

Table 8-2. Summary of acceptance criteria for offgas sampling.

Criteria	Control limits	Corrective action
Flow alignment	Average resultant angle within 20 degrees	Select different sample location or use EPA procedures for testing under cyclonic flow conditions
Isokinetic ratio	100 ± 10%	Qualify data
Final leak rate	≤0.02 acfm or 4% or sampling rate, whichever is less	Qualify data
Dry gas meter calibration	Post-average factor (Y_m) agree ±5% of pretest factor	Adjust sample volumes using the Y_m that gives smallest volume
Average correction factor	1.00 ± 10%	Adjust the dry gas meter and recalibrate
Intermediate dry gas meter	Calibrated annually against EPA standard	—
Analytical balance (top loader)	±0.1 g, National Institute of Standards and Technology Class F weights	Repair balance and recalibrate
Barometric pressure	Within 2.5-mm Hg of a mercury-in-glass	Recalibrate

Table 8-3. Acceptance criteria for offgas continuous monitoring equipment.

Criteria	Control limits	Corrective action
Concentration—stratification	±10% of mean	Select new sampling site
Zero and span drift (O_2, CO_2, CO, SO_2, and NO_x)	±3% of full scale	Apply correction to data
Zero and span drift	±5% of full scale or 10 ppm, whichever is larger	Apply correction to data
Leak rate	≤4% of normal flow at operating vacuum	Locate and repair leak
NO_2 converter test	≤2% conversion	Clean or replace converter
Linearity (O_2, CO_2, SO_2, NO_x)	±2% of full scale	Correct data and linearize analyzer
Bias (O_2)	≤0.5% O_2 response to zero gas	Locate and repair leak
Bias (SO_2, NO_x)	±5.0% response to zero gas	Correct data
CO_2 interference on CO	None	Correct data

9. QUALITY ASSURANCE

The QA plan for this program will include activities to (a) determine the quality of test results and (b) ensure a certain level of data quality based on data quality objectives. The level of data quality for many of the measurements and activities of this program will depend on yet-to-be-established performance of the melter facility, onsite sample collection and analysis equipment and procedures, and laboratory analytical procedures.

9.1 Quality Level

This type of test program is similar to an LITCO Quality Level C program. Level C programs are those that provide "items or services whose failure would not result in any significant health or safety risk to personnel, the loss or impairment of data generation, or inadequate quality of deliverable products or data; and the applicable codes, standards, or specifications do not require any acceptance verifications of other quality assuring activities."[14] Operation of the melter facility represents a significant health or safety risk to personnel in the event of some types of failure, but the operation will be performed by USBM operating personnel using their own safety, operating, and quality procedures to ensure operations safety as referenced in Section 12.

While unplanned failure of the melter operation and/or sampling, analytical, and monitoring procedures and equipment during the tests may cause the loss or impairment of some intended data generation, data meeting test objectives will still be generated. This is an applications evaluation, not a process control study or a regulatory trial production test. For example, accurate and valid particulate and metals sample analysis depends on stable operation of the melter and offgas and entrained fume flow conditions within specified parameters. Successful melter operation within the specified parameters has not yet been established for the various feed conditions. Therefore, the particulate and metals sample collection and analysis methods will be applied as rigorously as possible within the expediency and process limitations of the test conditions.

Testing will be performed to meet estimated data quality objectives based on the test methodologies. When the data quality objectives are not met, then the data quality may be impaired. However, the results will still meet the objectives of the test program as baseline data to interpret the melter performance and diagnostically evaluate the current melter design and operation.

The EPA's analogous quality level would be either Category III or IV. Category III projects are those "producing results for the purpose of evaluating and selecting basic options, or performing feasibility studies or preliminary assessments of unexplored areas that might lead to further work."[15] Category IV projects are those "producing results for the purpose of assessing suppositions."[12]

The primary feature of the Phase 1 test program is to research and develop innovative applications of melter technologies and obtain as much initial and baseline data as possible for planning subsequent, more detailed tests in Phases 2 and 3. Phase 1 is not being used for final evaluation of the technology applications, nor is it being used for regulatory development or compliance purposes. For these reasons, the LITCO Quality Level C (EPA Category III-IV) is appropriate for this test program.

The extensiveness of QC procedures is defined by the quality level assigned to the program and by the specifications in various test methodologies used in the test program. An EPA Category III project plan should include sections that describe the project, QA objectives, sampling and analysis procedures, data reduction, validation and reporting, and QC activities.[16] This project is described in Section 3. The sampling and analysis procedures are described in Sections 5 and 7. Data reduction, validation, and reporting are described in Sections 6 and 8. The applicable data quality objectives and QA activities are discussed below and in Sections 9.3 and 9.4.

9.1.1 Data Quality Objectives

Data quality objectives are either qualitative or quantitative statements defining the quality of data needed to support the program goals. The objectives are expressed in terms of accuracy, precision, and completeness. These terms are defined below:

- Accuracy is the difference in an average of measurements of a parameter, X, with an accepted reference or true value, T. It is usually expressed as the difference between the two values, X-T, or the difference as a percentage, 100 (X-T)/T. It is also sometimes expressed as a ratio, X/T. Accuracy is a measure of the bias in a method.

- Precision is a mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of standard deviations. Various measures of precision exist depending upon the "prescribed similar conditions."

- Completeness is the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions. Completeness is usually calculated as the number of valid measurements divided by the number of required or planned measurements times 100%.

The data quality objectives for the critical measurements in this test program are shown in Table 9-1. These data quality objectives will be used to support decisions concerning test validity and adequacy with respect to the program goals. Precision and accuracy for EPA reference method procedures are as prescribed by the EPA in 40 CFR 60 Appendix A as those required for a decision to be made regarding emissions compliance. Those indicated as EPA draft and other procedures have data quality objectives assigned at levels within the capabilities of the method, which may not yet be sufficiently documented.

The completeness levels are the minimum percentage typically achievable for sampling and analysis of this type. While it is not expected that any samples will be invalidated because of operator error, events such as power failures, failed connections, and broken glassware occasionally occur. For this reason, the completeness goals are not set at 100%. The completeness values also do not include the possibility of invalid measurements from failure of the pilot scale arc melter. Since this melter program is a research and development program rather than a routinely run process, the potential of melter operational failures during any given sample period is significant. Melter system operational failures will not affect the completeness of the various measurements.

Table 9-1. Data quality objectives for critical measurements.

Measurement	Reference or method	Precision (%)	Accuracy (%)	Completeness (%)
Feed additive weights, product weights	Magna-View Floor Scale (Howe Richardson Co.)	±1 lb	±1	90
Process temperatures	Thermocouples	ND	±1.5%	90
Static pressures	Pressure transducers	ND	±10	90
Feedrate	Calibrated feed screws	±5	±5	90
Gaseous flowrates	Pitot tubes, other flowmeters	ND	±10	90
Scrubber liquor rate	TBD	TBD	TBD	90
Scrubber blowdown rate	TBD	TBD	TBD	TBD
EPA 29 metals	EPA Draft Method 29	±50	±50[a]	80
EPA 29 total particulate	EPA Method 5 (from EPA Draft Method 29 Train)	±20	±20[a]	80
O_2, CO_2	EPA Method 3A	±10	±10	80
SO_2	EPA Method 6C	±10	±10	80
NO_x	EPA Method 7E	±10	±10	80
CO	EPA Method 10	±10	±10	80
Stack gas moisture from EPA 29 train	EPA Method 5 (from EPA Draft Method 29 Train)	±20	ND[b]	80
Stack gas velocity and flowrate from EPA 29 train	EPA Method 2 (from EPA Draft Method 29 Train)	ND	ND	80
Stack gas temperature from EPA 29 train	EPA Method 2 (from EPA Draft Method 29 Train)	ND	±3[c]	80
Process samples, full set metals[a,d]	SW846 6010 or 7000 series, USBM procedures	<20	±20	90
Process samples, P	AOAC method total phosphorous determination[e]	TBD	TBD	80
Process samples, S	LECO CS 144 gas analyzer	TBD	TBD	80
Process samples, total C	LECO CS 144	<20	±20	90
Process samples, Cl	USBM ALRC Cl Analysis	<20	±20	90

TBD = To Be Determined.

a. Analytical phase only.

b. Not determinable within limits of method precision.

c. Relative accuracy compared to thermometer.

d. Full set metals (18 metals)—Al, As, Ba, Ca, Ce, Cr, Cs, Cu, Fe, K, Mg, Na, Ni, Pb, Si, Ti, Zn, and Zr.

e. *Official Methods of analysis of the Official Agricultural Chemists*, 10th Edition, 1965, pages 11-13.

In the event that the specified completeness levels are not attained, corrective action will be taken immediately. However, much of the data validation will not be complete until after the testing phase has ended. In this case, it may not be possible to take corrective action to meet the data quality objectives (e.g., if the analytical laboratory irrecoverably contaminates or loses a sample).

9.2 Quality Control Methods

QC methods specified by the various testing, analytical, and routine procedures will be used to determine the quality of the test data and ensure that certain minimum quality objectives are achieved. QC activities will include data reduction, validation, and verification procedures as summarized in Section 8. QC activities will also include these features:

- Equipment maintenance and calibration procedures and schedules, controlled by the USBM and subcontractor personnel

- Standard calculation routines using hand-held calculators and computer spreadsheets, prepared and controlled by the USBM, LITCO or subcontractor personnel, depending on the specific program or spreadsheet

- Sample blanks, spikes, duplicates, and other analytical QC procedures as specified in the analytical procedures

- Organization and documentation of all calibration records, run sheets, data sheets, process logs, CEMS computer files and hard-copy data, calculation sheets, and spreadsheet files and printouts

- Internal QA audits and checks (see Section 9.4).

Equipment maintenance and calibrations are summarized in Sections 8, 10.3, and 10.4. Internal QA audits and checks are summarized in Section 9.4.

General QC checks that will be used during field testing and laboratory analysis are summarized in Section 8.4 and in Table 9-2. There are also a number of specific QC checks required for the specific test procedures. QC activities performed for manual sampling methods include

- Filter must be maintained at 250 ± 25°F. The probes and sample lines must be maintained at a temperature that prevents moisture condensation.

- Reading of the dry gas meter, ΔP, ΔH, temperature, and vacuum pump must be made during sampling at each traverse point.

- All sampling data forms will be reviewed daily. Incomplete or inaccurate data will not be acceptable.

- Only precleaned containers will be used to sample recovery.

Table 9-2. Internal QC checks.

Item	QC check	Frequency
Equipment	Inspect glassware for cracks; filters for tears, appearance; fittings for leaks; pitot tubes; probes for cleanliness; sample lines for cleanliness, leaks; general equipment set-up for ease of operation	Daily
Operation	Review specific procedure checklist items	Daily spot checks
Data records	Review calibration sheets, run sheets, operator logbooks, analytical sheets, tracking sheets, custody sheets for accuracy, completeness	Daily
Test results	Inspect for obvious errors, trends, completeness, precision, accuracy	Daily
Sample handling	Inspect sample containers before and after use for cleanliness, application; inspect sample labels for accuracy, completeness	Daily
Analytical results	Review for obvious errors, trends, blanks, spikes, recovery, completion of requested work, timeliness	Every receipt of analytical results

QC activities specific to particulate and metals sampling include

- Recording weights of filter from field blanks before and after train assembly to determine if filter tare weight is changed by handling.
- Calibration of analytical balance before and after particulate weights are determined.
- Visual inspection of system equipment, daily
- Monitoring of key temperatures, such as instrument, chiller, and line temperatures, every test
- Monitoring of sample flowrates, every test
- Interference checks to determine effects of one gas species on the detection of another species at least once at each site.

Internal control checks for the laboratory analysis methods include blanks, spikes, duplicates, and split samples as specified in the analytical procedures. A summary of the laboratory QC checks for the metals and particulate sampling is shown in Table 9-3. Where possible, the specified laboratory QC checks will be followed rigorously. Deviations from the specified QC checks will be made only when the deviations do not impair the usability of the test results for this test program.

Table 9-3. Internal QC sample matrix for particulate and metals measurements for the MMT samples and process samples.

QC sample type	Description	Analyze	Archive
Reagent blanks[a]	Filters 5% HNO_3/10% H_2O_2 Deionized water	Archive Archive Archive	1
Recovery blanks[b]	Acetone 0.1 N HNO_3	Archive Archive	1
Proof blanks	Complete train	Archive	1
Method QC	Per procedure except as modified in this test plan		
Spike sample[c]	Digested sample	None	
Split[d]	Digested sample	1 of each sample type, (slag, metal, and each APCS sample type, and MMT sample)	
Duplicate analysis[e]	Digested sample	1 of each sample type	

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a. Reagent blends are samples of unused raw reagents used in the sample collection process.

b. Recovery blanks are samples of unused solutions used for sample recovery.

c. Spike sample is the addition of a known amount of a standard to sample to evaluate matrix effects and other potential analytical artifacts on the analytical results. Spikes will be done only for a few yet-to-be determined analytes.

d. Split samples are those that are split into two or more portions, and each portion is analyzed.

e. Duplicate analysis is a repeat analysis on a separate aliquot of the original sample.

Such deviations will be made with the prior approval of the USBM Project Manager and LITCO Principal Investigator.

All pertinent offgas sampling records in the field will be documented and filed to ensure against loss of key data. Key records include

- Calibrations
- Maintenance records
- Manual method run sheets and weigh sheets.

Internal QA/QC checks for CEM testing include:

- Calibrations, every test
- Leak checks, every test
- Linearity checks, every 3 days or more frequently
- Bias checks, every 3 days or more frequently
- CEMS stripcharts and calibration sheets
- Process data sheets
- Hand calculator calculation forms
- Manual method computer spreadsheets, hard copies
- CEMS computer spreadsheets, hard copies
- Other computer spreadsheets, hard copies
- Floppy disks, manual method spreadsheets, CEMS data disks and spreadsheets, and process data
- QA audit sheets.

9.3 Routine Procedures

Standard operating procedures (SOPs) developed by the USBM test team or test and analytical procedures promulgated by the EPA will be observed where possible during the test program. QC activities relevant to these procedures are summarized in Section 9.2.

9.4 Internal Audit System

Internal QA audits and checks to ensure satisfactory completion of these activities will be conducted by the LITCO test director or designee. These audit activities include audit checklists, performance audits, control charts to visually show trends of key test results, and standard data sets to verify the accuracy of calculated results. The internal audits planned for this program are summarized in Table 9-4.

Table 9-4. Internal audits and QA checks.

Type of audit	Audit subject	When conducted
Systems	Data records—CEMS, manual sampling, process data collection	End of each test day
Performance	CEMS and manual method equipment field calibrations	Per EPA reference methodology
Control charts	Key results and calculations (key process temperatures, flowrates, pressures, % I, % moisture, velocity, flowrates O_2, CO_2, etc.) and for CEMS drift.	End of each test day
Control charts	Laboratory surrogate recoveries spikes, blanks, duplicates	During and/or after sample analysis
Performance	Hand calculator and computer spreadsheet	Once before use and after each modification

10. EQUIPMENT AND INSTRUMENTS

A variety of process equipment, test equipment, and process monitoring, sampling, and analytical instrumentation will be used during this test program. The melter process equipment and instrumentation is in place at the USBM ALRC. The main features and components are summarized in Section 3.

The sampling and analytical equipment is specified in the appropriate test procedures. The test procedures and key equipment items are summarized in Section 5. The analytical laboratory instrumentation is also specified in the applicable procedures, which are summarized in Section 7.

10.1 Range, Accuracy, and Tolerance Levels

The range, accuracy, and tolerance levels of the process monitoring and sampling equipment is subject to the design and operation of the melter facility. These specifications were designed to be appropriate for safe and effective operation of the melter and allow sufficient tolerance of the instrumentation to the high temperatures of the process. Specific instrumentation that can be easily calibrated such as pitot tubes for the offgas flowrate monitoring will be calibrated. Other instrumentation is not readily calibrated. Instruments of this type will maintained and used according to manufacturer's specifications to ensure accuracy and reliability of the results.

The range, accuracy, and tolerance levels of the offgas monitoring and sampling equipment and analytical equipment are specified in the test methodologies. To the extent possible, these performance levels will be strictly complied with during the test program. The test methodologies are referenced in Sections 5 and 7.

10.2 Calibration and Standardization Procedures

Calibrations will be performed according to the specified procedures discussed in Sections 5, 7, and 8 for field measurements, laboratory analyses, and QA activities. Some deviations may be necessary from the specified laboratory instrument calibrations, because reliable calibration standards for some analytes may not be available.

10.3 Preventive Maintenance

Preventive maintenance is performed for the melter system to ensure proper and safe operation of all components. Preventive maintenance for the sampling and analytical equipment is done to help ensure accurate and reliable measurements and sample collection. Before testing, all melter system components, instrumentation, and sample equipment will be inspected and checked for proper operation. Preventive maintenance for the melter system and test equipment will continue during the demonstration tests. The most critical equipment that will be inspected and maintained on a daily basis include

- Melter system: Feed motors, augers, hoppers, feed tubes, furnace roof, refractory, tapping fixture, and APCS ducting.

- **Instrumentation:** Thermocouples, pressure transducers, flowmeters, sample pumps and lines, pitot tubes, sample conditioning equipment, and CEMS instrumentation.

11. SUPPLIES, UTILITIES, AND FACILITIES

The expected necessary facilities and utilities are already in place at the ALRC. Supplies are also available at the ALRC, but specific reagents and materials needed for the test series will be maintained on-hand at the melter facility.

12. HEALTH AND SAFETY

The USBM ALRC has an operations safety plan administered through the following documents:

1. Chemical Hygiene Plan, January 22, 1991
2. Procedures for Startup and Resumed Activities, October 20, 1992
3. Job Safety Analysis for Operation of Three-Phase Electric Arc Melting Furnace, May 4, 1993
4. Standard Operating Procedure, Waste Calcining Facility Arc Melting Furnace, May 4, 1993.

These documents also entail SOPs for operating the melter and ancillary equipment.

The following potentially hazardous conditions are possible during the melting tests:

- Hot surfaces and molten slags and metals
- Large volumes of hot flammable gases (such as CO, H_2, CH_4,) and poisonous gases (CO, HCl, NO_x) will be produced within the furnace
- Fugitive emissions from various locations in the melter system.

Reasonable steps that will be taken to ensure safe operation, including

- Roof fan will be replaced with three silent models that will change the air in the building every 2 minutes.
- Continuous monitors for HCl and NO_x will be used to indicate and warn of furnace emissions.
- Appropriate personnel protective equipment (PPE) will be required for all test personnel. Personal air supply systems also will be required when the monitors indicate that respirators are insufficient for personnel protection. All personnel attending the furnace shall wear protective clothing, gloves, boots, and hard hats. Heat resistant suits are required for the tapping crew.
- Control room will be provided with a positive air supply to protect the furnace operator and support personnel.
- Mandatory safety review and discussion of test procedures will be conducted before the test series for all test team personnel.

13. RESIDUALS MANAGEMENT

Residuals from this test program will include the (a) slag, metal, and APCS solids, (b) a large number of samples, (c) possibly some spent baghouse bags, and (c) unused feed materials. The responsibility for handling and disposal of these residuals presently resides with both USBM and with LITCO.

Any untreated, unprocessed surrogate waste will be stored at the ALRC for use in additional waste feed characterization studies and in the planned Phase 3 tests. The secondary streams residuals are expected to be nonhazardous, and TCLP analyses will be performed to verify this assumption. Portions of the secondary stream materials will be archived for use in any additional studies, while the remainder will be disposed of at the local landfill. Any nonhazardous samples that are no longer needed in the archive will also be disposed of in the local landfill.

Some of the APCS solids may be hazardous. These will be disposed of (when no longer needed in archive) using an approved, certified, hazardous waste disposal company.

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Appendix A

BWID Nominal Standard Waste Mixture Tables

Table A-1. Additive compositions for the BWID Phase 2 feed mixtures.

	Composition in Weight %							Design Composition of Feed Mixtures (%)					Design Composition of Feed Mixtures (%) Renormalized for Added Spikes and Buffer				
Component	Hazardous Metals	Solid Combustibles	Silicated Organics (743)	Nitrate (Evaporator) Salts (745)	Metal Hydroxide Sludges (741, 742)	Nominal Composition	Total of Each Group in Nom. Comp.	Nom-90	Nom-80	Nom-70	Nom-60	Nom-50	Nom-90	Nom-80	Nom-70	Nom-60	Nom-50
Ce spike													0.50	0.50	0.50	0.50	0.50
Soil								90.00	80.00	70.00	60.00	50.00	67.72	59.12	50.98	43.17	35.60
Lime													19.69	17.10	14.64	12.27	9.97
Mill scale													4.51	8.38	11.82	14.94	17.82
Carbon steel	60.00					22.50		2.25	4.50	6.75	9.00	11.25	1.71	3.35	4.96	6.55	8.12
Stainless steel	30.50					11.44		1.14	2.29	3.43	4.58	5.72	0.87	1.70	2.52	3.33	4.13
Aluminum	5.00					1.88		0.19	0.38	0.56	0.75	0.94	0.14	0.28	0.41	0.55	0.68
Zirconium	2.50					0.94		0.09	0.19	0.28	0.38	0.47	0.07	0.14	0.21	0.27	0.34
Copper	1.50					0.56		0.06	0.11	0.17	0.23	0.28	0.04	0.08	0.12	0.16	0.20
Lead	0.50					0.19	37.50	0.02	0.04	0.06	0.08	0.09	0.01	0.03	0.04	0.05	0.07
LD Polyethylene, (-CH2-CH2-)		22.00				5.50		0.55	1.10	1.65	2.20	2.75	0.42	0.82	1.21	1.60	1.99
Wood pellets (paper), (C6H10O5)n		13.00				3.25		0.33	0.65	0.98	1.30	1.63	0.25	0.48	0.72	0.95	1.17
Wood pellets (wood), (C6H10O5)n		46.00				11.50		1.15	2.30	3.45	4.60	5.75	0.87	1.71	2.54	3.35	4.15
Neoprene rubber, (-CH2CCl-CHCH2-)n		10.00				2.50		0.25	0.50	0.75	1.00	1.25	0.19	0.37	0.55	0.73	0.90
Oil Dri sorbent		6.00				1.50		0.15	0.30	0.45	0.60	0.75	0.11	0.22	0.33	0.44	0.54
Wood pellets (cloth), (C6H10O5)n		3.00				0.75	25.00	0.08	0.15	0.23	0.30	0.38	0.06	0.11	0.17	0.22	0.27
Texaco Regal Oil, (CH2)n			18.03			4.06		0.41	0.81	1.22	1.62	2.03	0.31	0.60	0.89	1.18	1.46
Hydraulic oil, (CH2)n			18.67			4.20		0.42	0.84	1.26	1.68	2.10	0.32	0.63	0.93	1.22	1.52
Wheel bearing grease, (CH2)n			2.18			0.49		0.05	0.10	0.15	0.20	0.25	0.04	0.07	0.11	0.14	0.18
PVC, (-CH3Cl-)			30.32			6.82		0.68	1.36	2.05	2.73	3.41	0.52	1.02	1.51	1.99	2.46
Microcel E			26.67			6.00		0.60	1.20	1.80	2.40	3.00	0.45	0.89	1.32	1.75	2.17
Oil Dri			4.00			0.90		0.09	0.18	0.27	0.36	0.45	0.07	0.13	0.20	0.26	0.32
HD Polyethylene, (-CH2-CH2-)			0.18			0.04	22.51	0.00	0.01	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.01
NaNO3				54.00		2.70		0.27	0.54	0.81	1.08	1.35	0.20	0.40	0.60	0.79	0.97
KNO3				27.00		1.35		0.14	0.27	0.41	0.54	0.68	0.10	0.20	0.30	0.39	0.49
NaCl				3.06		0.15		0.02	0.03	0.05	0.06	0.08	0.01	0.02	0.03	0.04	0.06
Na2SO4				2.97		0.15		0.01	0.03	0.04	0.06	0.07	0.01	0.02	0.03	0.04	0.05
NaOH				2.97		0.15		0.01	0.03	0.04	0.06	0.07	0.01	0.02	0.03	0.04	0.05
Water				9.82		0.49		0.05	0.10	0.15	0.20	0.25	0.04	0.07	0.11	0.14	0.18
LD Polyethylene, (-CH2-CH2-)				0.18		0.01	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al(OH)3					11.50	1.15		0.12	0.23	0.35	0.46	0.58	0.09	0.17	0.25	0.33	0.42
Fe(OH)3					10.80	1.08		0.11	0.22	0.32	0.43	0.54	0.08	0.16	0.24	0.31	0.39
Ca(OH)2					6.60	0.66		0.07	0.13	0.20	0.26	0.33	0.05	0.10	0.15	0.19	0.24
Mg(OH)2					7.90	0.79		0.08	0.16	0.24	0.32	0.40	0.06	0.12	0.17	0.23	0.29
KHO					7.40	0.74		0.07	0.15	0.22	0.30	0.37	0.06	0.11	0.16	0.22	0.27
H2O					44.02	4.40		0.44	0.88	1.32	1.76	2.20	0.33	0.66	0.97	1.28	1.59
Portland Cement					11.60	1.16		0.12	0.23	0.35	0.46	0.58	0.09	0.17	0.26	0.34	0.42
LD Polyethylene, (-CH2-CH2-)					0.18	0.02		0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01
							10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	100.00	100.00	100.04	100.00	100.00	100.01	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Added lime (lb/100 lb Nom-xx mixture)								25.98	22.94	19.90	16.86	13.81					
Added mill scale (lb/100 lb Nom-xx mixture)								5.94339	11.24699	16.07535	20.53102	24.68387					

Notes:

1. Stainless steel is assumed to be 304 SS.
2. Calcium silicate is CaSiO3.
3. Oil Dri is fumed silica (SiO2).
4. The design composition is calculated using the Nom-xx proportion of soil and waste materials, with (1) added lime to buffer each mixture to a basicity ratio of 0.7, and (2) added spikes for cerium and samarium (TRU surrogates).

Table A-2. Calculated species compositions for the BWID Phase 2 feed mixtures.

Species	Lime	Normalized RWMC Soil	Mill scale	Nominal Waste	Design Composition of Feed Mixtures (%)					Design Composition of Feed Mixtures (%) Renormalized for Added Spikes and Buffer				
					NOM-90 Feed	NOM-80 Feed	NOM-70 Feed	NOM-60 Feed	NOM-50 Feed	NOM-90 Feed	NOM-80 Feed	NOM-70 Feed	NOM-60 Feed	NOM-50 Feed
Ce spike										0.50	0.50	0.50	0.50	0.50
Soil					90.00	80.00	70.00	60.00	50.00	67.72	59.12	50.98	43.17	35.60
Lime										19.69	17.10	14.64	12.27	9.97
Mill scale										4.51	8.38	11.82	14.94	17.82
Ag2O		8.4e-4			7.5e-4	6.7e-4	5.9e-4	5.0e-4	4.2e-4	5.7e-4	5.0e-4	4.3e-4	3.6e-4	3.0e-4
Al				1.88	0.19	0.38	0.56	0.75	0.94	0.15	0.29	0.42	0.56	0.69
Al(OH)3				1.15	0.12	0.23	0.35	0.46	0.58	0.09	0.18	0.26	0.34	0.42
Al2O3	0.45	10.16		0.39	9.19	8.21	7.23	6.25	5.28	7.00	6.15	5.34	4.56	3.81
As	2.0e-4				0	0	0	0	0	3.9e-5	3.4e-5	2.9e-5	2.5e-5	2.0e-5
As2O		1.2e-3			1.1e-3	9.5e-4	8.3e-4	7.1e-4	6.0e-4	8.1e-4	7.0e-4	6.1e-4	5.1e-4	4.2e-4
BaO		9.8e-3			8.8e-3	7.8e-3	6.8e-3	5.9e-3	4.9e-3	6.6e-3	5.8e-3	5.0e-3	4.2e-3	3.5e-3
C				21.62	2.16	4.32	6.49	8.65	10.81	1.75	3.33	4.88	6.40	7.91
Ca(OH)2				0.66	0.07	0.13	0.20	0.26	0.33	0.05	0.10	0.15	0.20	0.24
CaCO3		12.69			11.42	10.15	8.88	7.61	6.35	8.59	7.50	6.47	5.48	4.52
CaO	96.00	0.11		2.31	0.33	0.55	0.77	0.99	1.21	19.17	16.83	14.63	12.51	10.46
CdO		5.6e-5			5.0e-5	4.5e-5	3.9e-5	3.3e-5	2.8e-5	3.8e-5	3.3e-5	2.8e-5	2.4e-5	2.0e-5
CeO2		5.4e-3			4.9e-3	4.3e-3	3.8e-3	3.2e-3	2.7e-3	3.7e-3	3.2e-3	2.8e-3	2.3e-3	1.9e-3
Cl		3.9e-3		4.87	0.49	0.98	1.46	1.95	2.44	0.40	0.75	1.10	1.44	1.78
CO2	0.80				0	0	0	0	0	0.16	0.14	0.12	0.10	0.08
Cr				2.06	0.21	0.41	0.62	0.82	1.03	0.17	0.32	0.47	0.61	0.75
Cr2O3		0.03	0.13		0.03	0.02	0.02	0.02	0.01	0.03	0.03	0.03	0.03	0.03
Cs2O		5.2e-3			4.7e-3	4.1e-3	3.6e-3	3.1e-3	2.6e-3	3.5e-3	3.1e-3	2.6e-3	2.2e-3	1.8e-3
Cu				0.56	0.06	0.11	0.17	0.23	0.28	0.05	0.09	0.13	0.17	0.21
CuO		5.5e-3	0.33		4.9e-3	4.4e-3	3.8e-3	3.3e-3	2.7e-3	0.02	0.03	0.04	0.05	0.06
F	0.03				0	0	0	0	0	5.9e-3	5.1e-3	4.4e-3	3.7e-3	3.0e-3
Fe				30.92	3.09	6.18	9.28	12.37	15.46	2.50	4.76	6.98	9.16	11.32
Fe(OH)3				1.08	0.11	0.22	0.32	0.43	0.54	0.09	0.17	0.24	0.32	0.40
Fe2O3	0.12			0.12	0.01	0.02	0.04	0.05	0.06	0.03	0.04	0.05	0.05	0.06
Fe3O4		4.13	99.09		3.72	3.30	2.89	2.48	2.06	7.26	10.75	13.82	16.59	19.13

Table A-2. (continued)

H				3.34	0.33	0.67	1.00	1.34	1.67	0.27	0.51	0.75	0.99	1.22
H_2O		9.86		7.16	9.59	9.32	9.05	8.78	8.51	7.26	6.93	6.64	6.38	6.13
Hf				9.4e-4	9.4e-5	1.9e-4	2.8e-4	3.8e-4	4.7e-4	7.6e-5	1.4e-4	2.1e-4	2.8e-4	3.4e-4
HgO		1.1e-5			9.5e-6	8.4e-6	7.4e-6	6.3e-6	5.3e-6	7.1e-6	6.2e-6	5.4e-6	4.6e-6	3.8e-6
K_2O		2.36		0.05	2.13	1.90	1.67	1.44	1.21	1.60	1.40	1.22	1.03	0.86
KNO_3				1.35	0.14	0.27	0.41	0.54	0.68	0.11	0.21	0.30	0.40	0.49
KOH				0.74	0.07	0.15	0.22	0.30	0.37	0.06	0.11	0.17	0.22	0.27
$Mg(OH)_2$				0.79	0.08	0.16	0.24	0.32	0.40	0.06	0.12	0.18	0.23	0.29
MgO	0.50	2.22		0.06	2.00	1.79	1.57	1.36	1.14	1.60	1.41	1.22	1.04	0.86
Mn				8.4e-4	8.4e-5	1.7e-4	2.5e-4	3.4e-4	4.2e-4	6.8e-5	1.3e-4	1.9e-4	2.5e-4	3.1e-4
Mn_2O_3				8.1e-4	8.1e-5	1.6e-4	2.4e-4	3.2e-4	4.1e-4	6.6e-5	1.3e-4	1.8e-4	2.4e-4	3.0e-4
MnO_2	0.05		0.85		0	0	0	0	0	0.05	0.08	0.11	0.13	0.16
Mo				0.04	4.4e-3	8.8e-3	0.01	0.02	0.02	3.6e-3	6.8e-3	9.9e-3	0.01	0.02
N				0.06	5.8e-3	0.01	0.02	0.02	0.03	4.7e-3	8.9e-3	0.01	0.02	0.02
Na_2O	0.03	1.25		0.04	1.13	1.01	0.89	0.77	0.65	0.86	0.75	0.65	0.56	0.46
Na_2SO_4				0.15	0.01	0.03	0.04	0.06	0.07	0.01	0.02	0.03	0.04	0.05
NaCl				0.15	0.02	0.03	0.05	0.06	0.08	0.01	0.02	0.03	0.05	0.06
$NaNO_3$				2.70	0.27	0.54	0.81	1.08	1.35	0.22	0.42	0.61	0.80	0.99
NaOH				0.15	0.01	0.03	0.04	0.06	0.07	0.01	0.02	0.03	0.04	0.05
Ni				0.92	0.09	0.18	0.27	0.37	0.46	0.07	0.14	0.21	0.27	0.33
NiO		4.2e-3	0.19		3.8e-3	3.4e-3	3.0e-3	2.5e-3	2.1e-3	0.01	0.02	0.02	0.03	0.04
O				7.63	0.76	1.53	2.29	3.05	3.82	0.62	1.18	1.72	2.26	2.79
P_2O_5	0.02			2.3e-3	2.3e-4	4.6e-4	7.0e-4	9.3e-4	1.2e-3	4.1e-3	3.8e-3	3.5e-3	3.1e-3	2.8e-3
Pb	5.0e-4			0.19	0.02	0.04	0.06	0.08	0.09	0.02	0.03	0.04	0.06	0.07
PbO		2.4e-3			2.2e-3	1.9e-3	1.7e-3	1.5e-3	1.2e-3	1.6e-3	1.4e-3	1.2e-3	1.0e-3	8.6e-4
PO_4		0.28	0.04		0.25	0.23	0.20	0.17	0.14	0.19	0.17	0.15	0.13	0.11
S				0.03	3.1e-3	6.1e-3	9.2e-3	0.01	0.02	2.5e-3	4.7e-3	6.9e-3	9.1e-3	0.01
SeO		1.2e-4			1.1e-4	9.4e-5	8.2e-5	7.0e-5	5.9e-5	7.9e-5	6.9e-5	6.0e-5	5.1e-5	4.2e-5
Si				0.01	1.4e-3	2.8e-3	4.2e-3	5.6e-3	7.0e-3	1.1e-3	2.2e-3	3.2e-3	4.2e-3	5.1e-3
SiO_2	1.50	56.39	0.21	5.74	51.33	46.26	41.20	36.13	31.07	38.96	34.50	30.29	26.26	22.37
SO_3	0.20			0.03	2.9e-3	5.8e-3	8.8e-3	0.01	0.01	0.04	0.04	0.04	0.03	0.03
SO_4		0.04			0.04	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.01
TiO_2	0.05	0.42		4.9e-3	0.38	0.34	0.30	0.25	0.21	0.29	0.26	0.22	0.19	0.16
ZnO		9.8e-3			8.8e-3	7.8e-3	6.8e-3	5.9e-3	4.9e-3	6.6e-3	5.8e-3	5.0e-3	4.2e-3	3.5e-3
Zr				0.87	0.09	0.17	0.26	0.35	0.44	0.07	0.13	0.20	0.26	0.32
ZrO_2		9.8e-3			8.8e-3	7.8e-3	6.8e-3	5.9e-3	4.9e-3	6.6e-3	5.8e-3	5.0e-3	4.2e-3	3.5e-3
Total	99.8	100.0	100.8	99.8	100.0	100.0	100.0	99.9	99.9	100.0	100.0	100.0	100.1	100.1

Appendix B

Calculated Proximate Analysis for the BWID Phase 2 Feed Mixtures

Table B-1. Calculated proximate analysis of Nom-90 feed mixture.

		Composition (wt %)															
			Volatile		Nitrate Decomposition Loss				Carbonate Decomposition Loss		Sulfate Decomposition Loss		Chloride Evolution Loss				
Component	NOM-90	Moisture Loss	Organics Loss	H2O	N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2	Fixed Carbon	Solid Inerts	Total
Ce spike	0.50															100	100
Soil	67.7	9.9								5.58	0.03	0.01		0.01		84.5	100
Lime	19.7									0.80	0.15	0.08				99.0	100
Mill scale	4.51															100	100
Carbon steel	1.71														0.20	100	100
Stainless steel	0.87															100	100
Aluminum	0.14															100	100
Zirconium	0.07															100	100
Copper	0.04															100	100
Lead	0.01															100	100
Polyethylene	0.42		100														100
Wood pellets (paper)	0.25	10.0	70.0												20.0		100
Wood pellets (wood)	0.87	10.0	70.0												20.0		100
Rubber	0.19		100														100
Oil Dri sorbent	0.11	4.00														96.0	100
Wood pellets (cloth)	0.06	10.0	70.0												20.0		100
Texaco Regal Oil	0.31		100														100
Hydraulic oil	0.32		100														100
Wheel bearing grease	0.04		90.0												10.0		100
PVC	0.52		24.5										47.7	10.3	17.5		100
Microcel E	0.45	10.0														90.0	100
Oil Dri	0.07	4.00														96.0	100
NaNO3	0.20				11.0	39.5	9.4	3.61								36.5	100
KNO3	0.10				9.2	33.3	7.92	3.04								46.7	100
NaCl	0.01												62.4			37.6	100
Na2SO4	0.01										45.1	11.3				43.6	100
NaOH	0.01			22.5												77.5	100
H2O	0.37	100															100
Al(OH)3	0.09			34.6												65.4	100
Fe(OH)3	0.08			25.3												74.7	100
Ca(OH)2	0.05			24.3												75.7	100
Mg(OH)2	0.06			30.9												69.1	100
KOH	0.06			16.1												83.9	100
Portland Cement	0.09	1.49									1.95	0.97				95.6	100
Mixture Averages	**100**	**7.22**	**2.22**	**0.09**	**0.03**	**0.11**	**0.03**	**0.01**	**0.00**	**3.94**	**0.06**	**0.03**	**0.25**	**0.06**	**0.33**	**85.6**	**100**

Table B-2. Calculated proximate analysis of Nom-80 feed mixture.

	Composition (wt %)																
			Volatile		Nitrate Decomposition Loss				Carbonate Decomposition Loss		Sulfate Decomposition Loss		Chloride Evolution Loss				
Component	NOM-80	Moisture Loss	Volatile Organics Loss	H2O	N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2	Fixed Carbon	Solid Inerts	Total
Ce spike	0.50															100	100
Soil	59.1	9.9								5.58	0.03	0.01		0.01		84.5	100
Lime	17.1									0.80	0.15	0.08				99.0	100
Mill scale	8.38															100	100
Carbon steel	3.35														0.20	100	100
Stainless steel	1.70															100	100
Aluminum	0.28															100	100
Zirconium	0.14															100	100
Copper	0.08															100	100
Lead	0.03															100	100
Polyethylene	0.83		100														100
Wood pellets (paper)	0.48	10.0	70.0												20.0		100
Wood pellets (wood)	1.71	10.0	70.0												20.0		100
Rubber	0.37		100														100
Oil Dri sorbent	0.22	4.00														96.0	100
Wood pellets (cloth)	0.11	10.0	70.0												20.0		100
Texaco Regal Oil	0.60		100														100
Hydraulic oil	0.63		100														100
Wheel bearing grease	0.07		90.0												10.0		100
PVC	1.02		24.5										47.7	10.3	17.5		100
Microcel E	0.89	10.0														90.0	100
Oil Dri	0.13	4.00														96.0	100
NaNO3	0.40				11.0	39.5	9.4	3.61								36.5	100
KNO3	0.20				9.2	33.3	7.92	3.04								46.7	100
NaCl	0.02												62.4			37.6	100
Na2SO4	0.02										45.1	11.3				43.6	100
NaOH	0.02			22.5												77.5	100
H2O	0.73	100															100
Al(OH)3	0.17			34.6												65.4	100
Fe(OH)3	0.16			25.3												74.7	100
Ca(OH)2	0.10			24.3												75.7	100
Mg(OH)2	0.12			30.9												69.1	100
KOH	0.11			16.1												83.9	100
Portland Cement	0.17	1.49									1.95	0.97				95.6	100
Mixture Averages	**100**	**6.90**	**4.36**	**0.18**	**0.06**	**0.23**	**0.05**	**0.02**	**0.00**	**3.44**	**0.06**	**0.03**	**0.50**	**0.11**	**0.65**	**83.4**	**100**

PRXNOM80.XLS

Table B-3. Calculated proximate analysis of Nom-70 feed mixture.

	Composition (wt %)																
			Volatile		Nitrate				Carbonate		Sulfate		Chloride				
		Moisture	Organics		Decomposition Loss				Decomposition Loss		Decomposition Loss		Evolution Loss		Fixed	Solid	
Component	NOM-70	Loss	Loss	H2O	N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2	Carbon	Inerts	Total
Ce spike	0.50															100	100
Soil	51.0	9.9								5.58	0.03	0.01		0.01		84.5	100
Lime	14.6									0.80	0.15	0.08				99.0	100
Mill scale	11.8															100	100
Carbon steel	4.96														0.20	100	100
Stainless steel	2.52															100	100
Aluminum	0.41															100	100
Zirconium	0.21															100	100
Copper	0.12															100	100
Lead	0.04															100	100
Polyethylene	1.23		100														100
Wood pellets (paper)	0.72	10.0	70.0												20.0		100
Wood pellets (wood)	2.54	10.0	70.0												20.0		100
Rubber	0.55		100														100
Oil Dri sorbent	0.33	4.00														96.0	100
Wood pellets (cloth)	0.17	10.0	70.0												20.0		100
Texaco Regal Oil	0.89		100														100
Hydraulic oil	0.93		100														100
Wheel bearing grease	0.11		90.0												10.0		100
PVC	1.51		24.5										47.7	10.3	17.5		100
Microcel E	1.32	10.0														90.0	100
Oil Dri	0.20	4.00														96.0	100
NaNO3	0.60				11.0	39.5	9.4	3.61								36.5	100
KNO3	0.30				9.2	33.3	7.92	3.04								46.7	100
NaCl	0.03												62.4			37.6	100
Na2SO4	0.03										45.1	11.3				43.6	100
NaOH	0.03			22.5												77.5	100
H2O	1.08	100															100
Al(OH)3	0.25			34.6												65.4	100
Fe(OH)3	0.24			25.3												74.7	100
Ca(OH)2	0.15			24.3												75.7	100
Mg(OH)2	0.17			30.9												69.1	100
KOH	0.16			16.1												83.9	100
Portland Cement	0.26	1.49									1.95	0.97				95.6	100
Mixture Averages	**100**	**6.61**	**6.46**	**0.27**	**0.09**	**0.33**	**0.08**	**0.03**	**0.00**	**2.96**	**0.06**	**0.02**	**0.74**	**0.16**	**0.97**	**81.2**	**100**

PRXNOM70.XLS

Table B-4. Calculated proximate analysis of Nom-60 feed mixture.

	Composition (wt %)																
		Moisture	Volatile Organics		Nitrate Decomposition Loss				Carbonate Decomposition Loss		Sulfate Decomposition Loss		Chloride Evolution Loss		Fixed	Solid	
Component	NOM-60	Loss	Loss	H2O	N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2	Carbon	Inerts	Total
Ce spike	0.50															100	100
Soil	43.2	9.9								5.58	0.03	0.01		0.01		84.5	100
Lime	12.3									0.80	0.15	0.08				99.0	100
Mill scale	14.9															100	100
Carbon steel	6.55														0.20	100	100
Stainless steel	3.33															100	100
Aluminum	0.55															100	100
Zirconium	0.27															100	100
Copper	0.16															100	100
Lead	0.05															100	100
Polyethylene	1.62		100														100
Wood pellets (paper)	0.95	10.0	70.0												20.0		100
Wood pellets (wood)	3.35	10.0	70.0												20.0		100
Rubber	0.73		100														100
Oil Dri sorbent	0.44	4.00														96.0	100
Wood pellets (cloth)	0.22	10.0	70.0												20.0		100
Texaco Regal Oil	1.18		100														100
Hydraulic oil	1.22		100														100
Wheel bearing grease	0.14		90.0												10.0		100
PVC	1.99		24.5										47.7	10.3	17.5		100
Microcel E	1.75	10.0														90.0	100
Oil Dri	0.26	4.00														96.0	100
NaNO3	0.79				11.0	39.5	9.4	3.61								36.5	100
KNO3	0.39				9.2	33.3	7.92	3.04								46.7	100
NaCl	0.04												62.4			37.6	100
Na2SO4	0.04										45.1	11.3				43.6	100
NaOH	0.04			22.5												77.5	100
H2O	1.42	100															100
Al(OH)3	0.33			34.6												65.4	100
Fe(OH)3	0.31			25.3												74.7	100
Ca(OH)2	0.19			24.3												75.7	100
Mg(OH)2	0.23			30.9												69.1	100
KOH	0.22			16.1												83.9	100
Portland Cement	0.34	1.49									1.95	0.97				95.6	100
Mixture Averages	**100**	**6.34**	**8.53**	**0.36**	**0.12**	**0.44**	**0.11**	**0.04**	**0.00**	**2.51**	**0.06**	**0.02**	**0.98**	**0.21**	**1.28**	**79.0**	**100**

PRXNOM60.XLS

Table B-5. Calculated proximate analysis of Nom-50 feed mixture.

Component	Composition (wt %)																
	NOM-50	Moisture Loss	Volatile Organics Loss	H2O	Nitrate Decomposition Loss				Carbonate Decomposition Loss		Sulfate Decomposition Loss		Chloride Evolution Loss		Fixed Carbon	Solid Inerts	Total
					N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2			
Ce spike	0.50															100	100
Soil	35.6	9.9								5.58	0.03	0.01		0.01		84.5	100
Lime	10.0									0.80	0.15	0.08				99.0	100
Mill scale	17.8															100	100
Carbon steel	8.12														0.20	100	100
Stainless steel	4.13															100	100
Aluminum	0.68															100	100
Zirconium	0.34															100	100
Copper	0.20															100	100
Lead	0.07															100	100
Polyethylene	2.01		100														100
Wood pellets (paper)	1.17	10.0	70.0												20.0		100
Wood pellets (wood)	4.15	10.0	70.0												20.0		100
Rubber	0.90		100														100
Oil Dri sorbent	0.54	4.00														96.0	100
Wood pellets (cloth)	0.27	10.0	70.0												20.0		100
Texaco Regal Oil	1.46		100														100
Hydraulic oil	1.52		100														100
Wheel bearing grease	0.18		90.0												10.0		100
PVC	2.46		24.5										47.7	10.3	17.5		100
Microcel E	2.17	10.0														90.0	100
Oil Dri	0.32	4.00														96.0	100
NaNO3	0.97				11.0	39.5	9.4	3.61								36.5	100
KNO3	0.49				9.2	33.3	7.92	3.04								46.7	100
NaCl	0.06												62.4			37.6	100
Na2SO4	0.05										45.1	11.3				43.6	100
NaOH	0.05			22.5												77.5	100
H2O	1.77	100															100
Al(OH)3	0.42			34.6												65.4	100
Fe(OH)3	0.39			25.3												74.7	100
Ca(OH)2	0.24			24.3												75.7	100
Mg(OH)2	0.29			30.9												69.1	100
KOH	0.27			16.1												83.9	100
Portland Cement	0.42	1.49									1.95	0.97				95.6	100
Mixture Averages	**100**	**6.09**	**10.6**	**0.44**	**0.15**	**0.55**	**0.13**	**0.05**	**0.00**	**2.07**	**0.06**	**0.02**	**1.21**	**0.26**	**1.58**	**76.8**	**100**

PRXNOM50.XLS

Table B-6. Calculated proximate analysis of Nom-0 feed mixture.

Component	Composition (wt %)																
			Volatile		Nitrate				Carbonate		Sulfate		Chloride				
	Nominal	Moisture	Organics		Decomposition Loss				Decomposition Loss		Decomposition Loss		Evolution Loss		Fixed	Solid	
	Composition	Loss	Loss	H2O	N2	O2	NO	NO2	CO	CO2	SO2	O2	HCl	Cl2	Carbon	Inerts	Total
Carbon steel	22.5														0.20	100	**100**
Stainless steel	11.4															100	**100**
Aluminum	1.88															100	**100**
Zirconium	0.94															100	**100**
Copper	0.56															100	**100**
Lead	0.19															100	**100**
Polyethylene	5.57		100														**100**
Wood pellets (paper)	3.25	10.0	70.0												20.0		**100**
Wood pellets (wood)	11.5	10.0	70.0												20.0		**100**
Rubber	2.50		100														**100**
Oil Dri sorbent	1.50	4.00														96.0	**100**
Wood pellets (cloth)	0.75	10.0	70.0												20.0		**100**
Texaco Regal Oil	4.06		100														**100**
Hydraulic oil	4.20		100														**100**
Wheel bearing grease	0.49		90.0												10.0		**100**
PVC	6.82		24.5										47.7	10.3	17.5		**100**
Microcel E	6.00	10.0														90.0	**100**
Oil Dri	0.90	4.00														96.0	**100**
NaNO3	2.70				11.0	39.5	9.4	3.61								36.5	**100**
KNO3	1.35				9.2	33.3	7.92	3.04								46.7	**100**
NaCl	0.15												62.4			37.6	**100**
Na2SO4	0.15										45.1	11.3				43.6	**100**
NaOH	0.15			22.5												77.5	**100**
H2O	4.89	100															**100**
Al(OH)3	1.15			34.6												65.4	**100**
Fe(OH)3	1.08			25.3												74.7	**100**
Ca(OH)2	0.66			24.3												75.7	**100**
Mg(OH)2	0.79			30.9												69.1	**100**
KOH	0.74			16.1												83.9	**100**
Portland Cement	1.16	1.49									1.95	0.97				95.6	**100**
Mixture Averages	**100**	**7.16**	**29.3**	**1.23**	**0.42**	**1.52**	**0.36**	**0.14**	**0.00**	**0.00**	**0.09**	**0.03**	**3.35**	**0.70**	**4.39**	**51.3**	**100**

Appendix C

Estimated Offgas Compositions and Flowrates

Table C-1. Estimated offgas composition and flowrates.

Parameter		NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
		Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
FURNACE													
Offgas Composition													
O2, %		1.67	1.77	1.20	0.90	0.87	0.51	1.70	0.79	2.59	1.00	1.26	0.20
CO2, %		8.30	8.79	10.0	7.53	11.8	6.84	13.5	6.25	15.2	5.86	33.7	5.36
CO, ppm		8.06	85,309	12.2	91,823	16.3	94,897	20.3	94,328	24.3	93,814	60.7	96,726
NO, ppm		0.06	620	0.12	865	0.17	992	0.22	1,044	0.28	1,077	0.77	1,231
NO2, ppm		0.01	155	0.03	216	0.04	248	0.06	261	0.07	269	0.19	308
N2, %		39.6	41.9	63.3	47.5	87.1	50.7	115	53.3	143	55.0	360	57.4
SO2, ppm		0.06	589	0.06	420	0.06	328	0.06	264	0.06	222	0.09	143
HCl, ppm		0.45	4,737	0.88	6,605	1.30	7,579	1.72	7,977	2.13	8,226	5.90	9,407
Cl2, ppm		0.05	545	0.10	734	0.14	832	0.19	870	0.23	894	0.64	1,015
H2O, %		31.2	33.0	35.2	26.5	39.3	22.9	43.4	20.1	47.5	18.3	96.9	15.4
THC as CH2, ppm		5.08	53,777	10.0	74,995	14.8	86,046	19.5	90,563	24.2	93,399	67.0	106,805
	Total	94.5		133		172		215		259		628	
Offgas Flowrate, scfm			94.5		133		172		215		259		628
acfm			370		522		673		844		1,015		2,459
Offgas molecular weight, wt. basis			25.5		25.7		25.7		25.9		26.0		26.0
Offgas Flowrate, lb/hr			376		532		689		868		1,048		2,539
Offgas Flowrate, kg/hr			170		242		313		394		476		1,152
Specified Parameters													
	Feedrate, lb/hr		1,000		1,000		1,000		1,000		1,000		1,000
	Offgas Temperature, F		1,600		1,600		1,600		1,600		1,600		1,600
	Offgas Temperature, C		871		871		871		871		871		871
	Static pressure, in. H2O		- 1.00		- 1.00		- 1.00		- 1.00		- 1.00		- 1.00
	Air in-leakage, scfm		50.0		50.0		50.0		50.0		50.0		50.0
	Air injected, scfm		0.00		30.0		60.0		95.0		130		405
	% vol. organics to CO		25.0		25.0		25.0		25.0		25.0		25.0
	% vol. organics to CO2		25.0		25.0		25.0		25.0		25.0		25.0
	Graphite Elec. Cons. (lb/hr)		7.00		7.00		7.00		7.00		7.00		7.00
Notes:	1. All fixed C, including the graphite electrodes, is assumed to oxidize to CO.												
	2. Thermal NOx is assumed to be zero.												

Table C-1. continued.

Parameter	NOM-90 Flowrate scfm	NOM-90 Comp-osition	NOM-80 Flowrate scfm	NOM-80 Comp-osition	NOM-70 Flowrate scfm	NOM-70 Comp-osition	NOM-60 Flowrate scfm	NOM-60 Comp-osition	NOM-50 Flowrate scfm	NOM-50 Comp-osition	NOM-0 Flowrate scfm	NOM-0 Comp-osition
THERMAL OXIDIZER												
Offgas Composition												
O2, %	25.9	3.00	29.0	3.00	32.0	3.00	35.0	3.00	37.9	3.00	65.4	3.00
CO2, %	71.7	8.31	82.5	8.55	93.1	8.74	104	8.89	114	9.0	212	9.7
CO, ppm	*0.01*	10.0	*0.01*	10.0	*0.01*	10.0	*0.01*	10.0	*0.01*	10.0	*0.02*	10.0
NO, ppm	0.06	67.9	0.12	119	0.17	160	0.22	193	0.28	221	0.77	355
NO2, ppm	0.01	17.2	0.03	30.0	0.04	40.2	0.06	48.5	0.07	55.4	0.19	88.9
N2, %	628	72.8	708	73.3	785	73.6	861	73.9	937	74.1	1,630	74.8
SO2, ppm	0.06	64.5	0.06	57.9	0.06	52.8	0.06	48.8	0.06	45.5	0.09	41.2
HCl, ppm	0.55	638	1.08	1,114	1.59	1,490	2.09	1,797	2.59	2,054	7.18	3,294
H2O, %	136	15.8	145	15.0	154	14.5	163	14.0	172	13.6	264	12.1
THC as CH2, ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	863		966		1,066		1,165		1,263		2,179	
Offgas Flowrate, scfm		863		966		1,066		1,165		1,263		2,179
acfm		4,437		4,965		5,482		5,991		6,497		11,206
Offgas molecular weight, wt. basis		27.9		28.0		28.1		28.2		28.2		28.5
Offgas Flowrate, lb/hr		3,747		4,211		4,665		5,112		5,555		9,674
Offgas Flowrate, kg/hr		1,701		1,912		2,118		2,321		2,522		4,392
Heat capacity of offgas, J/mol*C		35.9		35.9		35.8		35.8		35.8		35.8
Operating Conditions												
Operating Temperature, F		2,250		2,250		2,250		2,250		2,250		2,250
Operating Temperature, C		1,232		1,232		1,232		1,232		1,232		1,232
Fuel Gas (CH4), scfm		50.0		50.0		50.0		50.0		50.0		50.0
Burner combustion air, scfm		564		564		564		564		564		564
Offgas combustion air, scfm		*181*		*252*		*319*		*381*		*441*		*1,043*

Notes:

1. Oxygen levels were based on the assumption of complete oxidation of CO and CH2, with 3% excess oxygen.
2. Assumed complete oxidation of CH2 with 0 ppm remaining in the thermal oxidizer offgas, which is considered good engineering practice for thermal oxidizers.
3. Assumed complete oxidation of CO with 10 ppm remaining in the thermal oxidizer offgas, which is considered good engineering practice for thermal oxidizers.
4. Shaded cells were calculated using an iterative goal-seek function that was based on changing the values in the italicized cells until the desired value was obtained in the shaded cell.

Table C-1. continued.

Parameter		NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
		Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
SPRAY QUENCH OUTLET													
Composition													
O2, %		25.9	1.82	29.0	1.82	32.0	1.82	35.0	1.82	37.9	1.82	65.4	1.82
CO2, %		71.7	5.04	82.5	5.18	93.1	5.30	104	5.39	114	5.47	212	5.90
CO, ppm		0.01	6.06	0.01	6.06	0.01	6.06	0.01	6.06	0.01	6.05	0.02	6.07
NO, ppm		0.06	41.1	0.12	72.3	0.17	97.0	0.22	117	0.28	134	0.77	215
NO2, ppm		0.01	10.4	0.03	18.2	0.04	24.4	0.06	29.4	0.07	33.6	0.19	53.9
N2, %		628	44.1	708	44.4	785	44.7	861	44.8	937	45.0	1,630	45.4
SO2, ppm		0.06	39.1	0.06	35.1	0.06	32.0	0.06	29.6	0.06	27.6	0.09	25.0
HCl, ppm		0.55	387	1.08	675	1.59	904	2.09	1,090	2.59	1,246	7.18	1,999
H2O, %		697	49.0	772	48.5	846	48.1	919	47.8	991	47.6	1,676	46.7
THC as CH2, ppm		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	1,424		1,593		1,758		1,921		2,083		3,591	
Spray quench outlet flowrate, scfm			1,424		1,593		1,758		1,921		2,083		3,591
acfm			2,625		2,936		3,241		3,542		3,840		6,621
Spray quench offgas mol. wt., wt. basis			24.0		24.1		24.1		24.2		24.2		24.4
Spray quench offgas flowrate, lb/hr			5,319		5,968		6,603		7,230		7,851		13,631
Spray quench offgas flowrate, kg/hr			2,415		2,710		2,998		3,282		3,564		6,189
Heat capacity - spray quench offgas, J/mol*C			33.1		33.1		33.0		33.0		33.0		33.0
Operating Conditions													
	Spray cooler outlet T (F)		500		500		500		500		500		500
	Spray cooler outlet T (C)		260		260		260		260		260		260
	Static pressure, in. H2O		- 5.00		- 5.00		- 5.00		- 5.00		- 5.00		- 5.00
	Added water (gal/min)		3.14		3.51		3.88		4.24		4.59		7.91

Table C-1. continued.

Parameter		NOM-90 Flowrate scfm	NOM-90 Composition	NOM-80 Flowrate scfm	NOM-80 Composition	NOM-70 Flowrate scfm	NOM-70 Composition	NOM-60 Flowrate scfm	NOM-60 Composition	NOM-50 Flowrate scfm	NOM-50 Composition	NOM-0 Flowrate scfm	NOM-0 Composition
AIR QUENCH OUTLET													
Composition													
O2, %		334	11.6	374	11.6	412	11.6	450	11.6	488	11.5	842	11.5
CO2, %		72.2	2.50	83.1	2.57	93.7	2.63	104	2.67	115	2.71	213	2.92
CO, ppm		0.01	2.98	0.01	2.98	0.01	2.98	0.01	2.98	0.01	2.98	0.02	2.99
NO, ppm		0.06	20.3	0.12	35.6	0.17	47.8	0.22	57.7	0.28	66.0	0.77	106
NO2, ppm		0.02	5.22	0.03	9.1	0.04	12.1	0.06	14.6	0.07	16.7	0.19	26.7
N2, %		1,788	61.8	2,004	62.0	2,216	62.1	2,424	62.2	2,631	62.2	4,550	62.4
SO2, ppm		0.06	19.3	0.06	17.3	0.06	15.8	0.06	14.6	0.06	13.6	0.09	12.3
HCl, ppm		0.55	190	1.08	333	1.59	445	2.09	537	2.59	614	7.18	985
H2O, %		697	24.1	772	23.9	846	23.7	919	23.6	991	23.4	1,676	23.0
THC as CH2, ppm		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	2,892		3,235		3,570		3,900		4,228		7,289	
Air quench outlet flowrate, scfm			2,892		3,235		3,570		3,900		4,228		7,289
acfm			4,221		4,721		5,210		5,693		6,171		10,639
Air quench offgas mol. wt., wt. basis			26.5		26.5		26.5		26.5		26.6		26.6
Air quench offgas flowrate, lb/hr			11,918		13,347		14,745		16,124		17,492		30,249
Air quench offgas flowrate, kg/hr			5,411		6,060		6,694		7,320		7,941		13,733
Operating Conditions													
	Air quench outlet T (F)		300		300		300		300		300		300
	Air quench outlet T (C)		149		149		149		149		149		149
	Static pressure, in. H2O		- 5.00		- 5.00		- 5.00		- 5.00		- 5.00		- 5.00
	Added air, scfm		1,468		1,642		1,811		1,979		2,145		3,697
	Added air, kg/hr		2,955		3,305		3,646		3,983		4,318		7,442

Table C-1. continued.

Parameter	NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
BAGHOUSE												
Offgas Composition												
O2, %	345	11.7	384	11.7	423	11.7	461	11.7	499	11.7	852	11.6
CO2, %	72.2	2.45	83.1	2.53	93.8	2.59	104	2.64	115	2.68	213	2.90
CO, ppm	0.01	2.93	0.01	2.94	0.01	2.94	0.01	2.94	0.01	2.95	0.02	2.97
NO, ppm	0.06	19.9	0.12	35.1	0.17	47.1	0.22	57.0	0.28	65.2	0.77	105
NO2, ppm	0.02	5.14	0.03	8.93	0.04	11.9	0.06	14.4	0.07	16.5	0.19	26.5
N2, %	1,828	62.1	2,044	62.2	2,255	62.3	2,464	62.4	2,671	62.4	4,590	62.5
SO2, ppm	0.06	18.9	0.06	17.0	0.06	15.6	0.06	14.4	0.06	13.4	0.09	12.2
HCl, ppm	0.55	187	1.08	327	1.59	439	2.09	530	2.59	607	7.18	978
H2O, %	697	23.7	772	23.5	846	23.4	919	23.3	991	23.2	1,676	22.8
THC as CH2, ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2,942		3,285		3,620		3,950		4,278		7,339	
Offgas Flowrate, scfm		2,942		3,285		3,620		3,950		4,278		7,339
acfm		4,234		4,727		5,209		5,684		6,156		10,561
Offgas molecular weight, wt. basis		26.5		26.5		26.6		26.6		26.6		26.7
Offgas Flowrate, lb/hr		12,142		13,572		14,970		16,349		17,717		30,473
Offgas Flowrate, kg/hr		5,513		6,162		6,796		7,422		8,043		13,835
Operating Conditions												
Operating Temperature, F		280		280		280		280		280		280
Operating Temperature, C		138		138		138		138		138		138
Static pressure, in. H2O		- 10.00		- 10.00		- 10.00		- 10.00		- 10.00		- 10.00
Pulsed jet air, scfm		50.0		50.0		50.0		50.0		50.0		50.0

Table C-1. continued.

Parameter		NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
		Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
SCRUBBER OUTLET													
Composition													
O2, %		345	11.2	384	11.1	423	11.1	461	11.1	499	11.1	852	11.0
CO2, %		72.2	2.34	83.1	2.41	93.8	2.46	104	2.51	115	2.55	213	2.75
CO, ppm		0.01	2.80	0.01	2.80	0.01	2.80	0.01	2.80	0.01	2.80	0.02	2.81
NO, ppm		0.06	19.0	0.12	33.4	0.17	44.8	0.22	54.1	0.28	61.9	0.77	100
NO2, ppm		0.02	4.91	0.03	8.51	0.04	11.4	0.06	13.7	0.07	15.6	0.19	25.1
N2, %		1,828	59.3	2,044	59.3	2,255	59.3	2,464	59.3	2,671	59.3	4,590	59.1
SO2, ppm		0.00	0.18	0.00	0.16	0.00	0.15	0.00	0.14	0.00	0.13	0.00	0.12
HCl, ppm		0.01	3.58	0.02	6.24	0.03	8.35	0.04	10.1	0.05	11.5	0.14	18.5
H2O, %		835	27.1	935	27.1	1,032	27.1	1,128	27.1	1,223	27.1	2,105	27.1
THC as CH2, ppm		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	3,080		3,446		3,804		4,157		4,507		7,762	
Flowrate, scfm			3,080		3,446		3,804		4,157		4,507		7,762
acfm			3,737		4,181		4,616		5,044		5,469		9,418
Offgas molecular weight, wt. basis			26.1		26.1		26.1		26.1		26.1		26.2
Offgas flowrate, lb/hr			12,527		14,021		15,482		16,923		18,352		31,636
Offgas flowrate, kg/hr			5,687		6,366		7,029		7,683		8,332		14,363
Heat capacity of offgas, J/mol*C			30.7		30.7		30.7		30.7		30.7		30.7
Makeup H2O from evaporation, gpm			*0.78*		*0.91*		*1.04*		*1.17*		*1.30*		*2.41*
Makeup H2O from evaporation, kg/hr			*176*		*207*		*237*		*266*		*295*		*547*
Operating Conditions													
	Outlet Temperature, F		153		153		153		153		153		153
	Outlet Temperature, C		67.2		67.2		67.2		67.2		67.2		67.2
	Static pressure, in. H2O		- 17.00		- 17.00		- 17.00		- 17.00		- 17.00		- 17.00
	Scrubbing Efficiency %												
	SO2		99.0		99.0		99.0		99.0		99.0		99.0
	HCl		98.0		98.0		98.0		98.0		98.0		98.0
Note:	Shaded cells were calculated using an iterative goal-seek function that was based on changing the values in the italicized cells until the desired value was obtained in the shaded cell.												

Table C-1. continued.

Parameter	NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
	Flowrate scfm	Comp-osition	Flowrate scfm	Comp-osition	Flowrate scfm	Comp-osition	Flowrate scfm	Comp-osition	Flowrate scfm	Comp-osition	Flowrate scfm	Comp-osition
COOLER/CONDENSER												
Composition												
O2, %	345	14.6	384	14.6	423	14.5	461	14.5	499	14.5	852	14.3
CO2, %	72.2	3.06	83.1	3.15	93.8	3.22	104	3.28	115	3.32	213	3.59
CO, ppm	0.01	3.66	0.01	3.66	0.01	3.66	0.01	3.65	0.01	3.65	0.02	3.67
NO, ppm	0.06	24.8	0.12	43.6	0.17	58.5	0.22	70.7	0.28	80.8	0.77	130
NO2, ppm	0.02	6.41	0.03	11.1	0.04	14.8	0.06	17.9	0.07	20.4	0.19	32.7
N2, %	1,828	77.5	2,044	77.4	2,255	77.4	2,464	77.4	2,671	77.4	4,590	77.2
SO2, ppm	0.00	0.24	0.00	0.21	0.00	0.19	0.00	0.18	0.00	0.17	0.00	0.15
HCl, ppm	0.01	4.67	0.02	8.15	0.03	10.9	0.04	13.2	0.05	15.0	0.14	24.2
H2O, %	*114*	4.84	*128*	4.84	*141*	4.84	*154*	4.84	*167*	4.84	*288*	4.84
THC as CH2, ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2,359		2,639		2,913		3,184		3,452		5,944	
Flowrate, scfm		2,359		2,639		2,913		3,184		3,452		5,944
acfm		2,581		2,888		3,188		3,484		3,777		6,504
H2O cond. from gas, kg/hr	919		1,028		1,135		1,240		1,344		2,315	
H2O cond. from gas, gpm	4.04		4.52		4.99		5.46		5.92		10.2	
Offgas molecular weight, wt. basis		28.6		28.6		28.6		28.6		28.6		28.7
Offgas flowrate, lb/hr		10,505		11,759		12,985		14,194		15,393		26,541
Offgas flowrate, kg/hr		4,769		5,339		5,895		6,444		6,988		12,050
Operating Conditions												
Outlet Temperature, F		90.0		90.0		90.0		90.0		90.0		90.0
Outlet Temperature, C		32.2		32.2		32.2		32.2		32.2		32.2
Static pressure, in. H2O		- 19.00		- 19.00		- 19.00		- 19.00		- 19.00		- 19.00
Condenser water, gal/min		8.77		9.8		10.8		11.8		12.8		22.1

Notes:
1. Assumes cond. H2O T of 60 F, and approach T of 23 F
2. Shaded cells were calculated using an iterative goal-seek function that was based on changing the values in the italicized cells until the desired value was obtained in the shaded cell.

Table C-1. continued.

Parameter		NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
		Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
REHEAT													
Composition													
O2, %		345	14.6	384	14.6	423	14.5	461	14.5	499	14.5	852	14.3
CO2, %		72.2	3.06	83.1	3.15	93.8	3.22	104	3.28	115	3.32	213	3,59
CO, ppm		0.01	3.66	0.01	3.66	0.01	3.66	0.01	3.65	0.01	3.65	0.02	3.67
NO, ppm		0.06	24.8	0.12	43.6	0.17	58.5	0.22	70.7	0.28	80.8	0.77	130
NO2, ppm		0.02	6.41	0.03	11.1	0.04	14.8	0.06	17.9	0.07	20.4	0.19	32.7
N2, %		1,828	77.5	2,044	77.4	2,255	77.4	2,464	77.4	2,671	77.4	4,590	77.2
SO2, ppm		0.00	0.24	0.00	0.21	0.00	0.19	0.00	0.18	0.00	0.17	0.00	0.15
HCl, ppm		0.01	4.67	0.02	8.15	0.03	10.9	0.04	13.2	0.05	15.0	0.14	24.2
H2O, %		114	4.84	128	4.84	141	4.84	154	4.84	167	4.84	288	4.84
THC as CH2, ppm		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	2,359		2,639		2,913		3,184		3,452		5,944	
Flowrate, scfm			2,359		2,639		2,913		3,184		3,452		5,944
	acfm		2,658		2,974		3,283		3,588		3,890		6,699
Offgas molecular weight, wt. basis			28.6		28.6		28.6		28.6		28.6		28.7
Offgas flowrate, lb/hr			10,505		11,759		12,985		14,194		15,393		26,541
Offgas flowrate, kg/hr			4,769		5,339		5,895		6,444		6,988		12,050
Operating Conditions													
	Outlet Temperature, F		105		105		105		105		105		105
	Outlet Temperature, C		40.6		40.6		40.6		40.6		40.6		40.6
	Static pressure, in. H2O		- 20.00		- 20.00		- 20.00		- 20.00		- 20.00		- 20.00

Table C-1. continued.

Parameter	NOM-90		NOM-80		NOM-70		NOM-60		NOM-50		NOM-0	
	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition	Flowrate scfm	Composition
INDUCED DRAFT FAN												
Composition												
O2, %	345	14.6	384	14.6	423	14.5	461	14.5	499	14.5	852	14.3
CO2, %	72.2	3.06	83.1	3.15	93.8	3.22	104	3.28	115	3.32	213	3.59
CO, ppm	0.01	3.66	0.01	3.66	0.01	3.66	0.01	3.65	0.01	3.65	0.02	3.67
NO, ppm	0.06	24.8	0.12	43.6	0.17	58.5	0.22	70.7	0.28	80.8	0.77	130
NO2, ppm	0.02	6.41	0.03	11.1	0.04	14.8	0.06	17.9	0.07	20.4	0.19	32.7
N2, %	1,828	77.5	2,044	77.4	2,255	77.4	2,464	77.4	2,671	77.4	4,590	77.2
SO2, ppm	0.00	0.24	0.00	0.21	0.00	0.19	0.00	0.18	0.00	0.17	0.00	0.15
HCl, ppm	0.01	4.67	0.02	8.15	0.03	10.9	0.04	13.2	0.05	15.0	0.14	24.2
H2O, %	114	4.84	128	4.84	141	4.84	154	4.84	167	4.84	288	4.84
THC as CH2, ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2,359		2,639		2,913		3,184		3,452		5,944	
Flowrate, scfm		2,359		2,639		2,913		3,184		3,452		5,944
acfm		2,572		2,878		3,177		3,472		3,764		6,482
Offgas molecular weight, wt. basis		28.6		28.6		28.6		28.6		28.6		28.7
Offgas flowrate, lb/hr		10,505		11,759		12,985		14,194		15,393		26,541
Offgas flowrate, kg/hr		4,769		5,339		5,895		6,444		6,988		12,050
Operating Conditions												
Outlet Temperature, F		115		115		115		115		115		115
Outlet Temperature, C		46.1		46.1		46.1		46.1		46.1		46.1

Appendix D

Estimated Elemental Compositions of the Surrogate Mixture Components

Table D-1. Estimated elemental compositions of the surrogate additives used to prepare the surrogate waste mixtures.

Additive	Comp.
Lime	
CaO	96.0
SiO2	1.50
CO2	0.80
Fe2O3	0.12
Al2O3	0.45
MgO	0.50
SO3	0.20
MnO2	0.05
TiO2	0.05
Na2O	0.03
P2O5	0.02
F	0.03
Pb	0.00
As	0.00
Carbon steel	
Fe	99.8
C	0.20
Stainless steel	
Fe	74.0
Cr	18.0
Ni	8.00
Aluminum	100
Zirconium	
Zr	93.0
Mo	4.70
Si	1.50
Fe	0.40
Cr	0.30
Hf	0.10
Cu	0.09
Mn	0.09
Copper	100
Lead	100
Polyethylene	
C	85.6
H	14.4
Wood pellets (paper)	
C	34.5
H	6.54
O	48.9
N	0.09
Water	10.0

Additive	Comp.
Rubber	
C	54.3
H	5.70
Cl	40.0
Oil Dri sorbent	
SiO2	89.2
Al2O3	4.00
Fe2O3	1.50
CaO	0.50
MgO	0.30
Na2O	0.25
K2O	0.25
Water	4.00
Wood pellets (cloth)	
C	34.5
H	6.54
O	48.9
N	0.09
Water	10.0
Texaco Regal Oil	
C	85.6
H	12.0
S	0.35
O	0.60
N	0.50
Hydraulic oil	
C	85.6
H	12.0
S	0.35
O	0.60
N	0.50
Wheel bearing grease	
C	85.6
H	12.0
S	0.35
O	0.60
N	0.50
PVC	
C	38.4
H	4.85
Cl	56.7

Additive	Comp.
NaNO3	100
KNO3	100
NaCl	100
Na2SO4	100
NaOH	100
Water	100
Al(OH)3	100
Fe(OH)3	100
Ca(OH)2	100
Mg(OH)2	100
KOH	100
H2O	100
Portland Cement	
SiO2	21.0
Al2O3	5.80
Fe2O3	2.40
TiO2	0.42
Mn2O3	0.07
P2O5	0.20
SO3	2.52
CaO	64.0
MgO	1.24
Na2O	0.25
K2O	0.61
Water	1.49
Wood pellets (wood)	
C	34.5
H	6.54
O	48.9
N	0.09
Water	10.0
Microcel E	
SiO2	56.0
Al2O3	3.80
Fe2O3	1.00
CaO	26.0
MgO	0.70
Na2O	0.60
K2O	0.60
Water	10.0

Additive	Comp.
Soil	
Ag2O	0.00
Al2O3	10.41
As2O	0.00
BaO	0.01
CaCO3	13.00
CaO	0.11
CdO	0.00
CeO2	0.01
Cr2O3	0.03
Cs2O	0.01
CuO	0.01
Fe3O4	4.23
HgO	0.00
K2O	2.42
MgO	2.27
Na2O	1.28
NiO	0.00
PO4	0.29
PbO	0.00
SO4	0.04
SeO	0.00
SiO2	57.76
TiO2	0.43
ZnO	0.01
ZrO2	0.01
Cl	0.00
Water	10.10
Mill scale	
Cr2O3	0.13
CuO	0.33
Fe3O4	99.09
MnO2	0.85
NiO	0.19
PO4	0.04
SiO2	0.21

Appendix E

Reconciliation of the Test Plan to the BWID Technology Test Plan Guidance Document

Appendix E

Reconciliation of the Test Plan to the BWID Technology Test Plan Guidance Document

This test plan was prepared according to the *Buried Waste Integrated Demonstration Technology Test Plan* (EGG-WTD-9800, Rev. 1), with some deviations that were pertinent to this specific test program. This test plan has been written as a guide for those LITCO and U.S. Bureau of Mines personnel to perform the test program and meet the objectives specified in the Technical Task Plan. The test plan was organized to reduce redundancy, maintain this focus, and minimize distraction during day-to-day use of this test plan during the test program. Several of the sections specified in the general guidance document are not relevant to this program and were excluded. Some other sections have been reorganized so the test plan is more directly focused on the test program.

For completeness, the contents of the test plan and the recommended sections in the guidance document are reconciled in Table E-1.

Table E-1. Reconciliation of the test plan to the BWID technology test plan guidance document.

Section of the guidance document (EGG-WTD-9800, Rev.1, App. A)	Location where found in the test plan
ABSTRACT	ABSTRACT
ACRONYMS	ACRONYMS
1. INTRODUCTION	1. INTRODUCTION
1.1 Technology Description and Background	1.1 Technology Description and Background
1.2 Scope of Test	1.2 Scope
1.3 Objective of Test	1.3 Objectives
1.4 Technology Agreement	1.4 Technology Agreement
1.5 The customer need that the technology is satisfying	Customer needs are more completely defined in the Technical Task Plan (TTP), and will be satisfied by completion of the test objectives defined in the TTP and in Section 1.3.
2. ORGANIZATION AND RESPONSIBILITIES	2. ORGANIZATION AND RESPONSIBILITIES
2.1 Organizational Responsibilities chart	The chart is redundant with the text.
2.2 Responsibilities of performing organization	Section 2.1
2.3 Personnel Support Requirements	Section 2.1
2.4 Test Personnel Qualifications List	Section 2.1, to the extent necessary.
3. DESCRIPTION OF TEST	3. DESCRIPTION OF TEST - This section was organized to describe the facility first, as necessary, to enable the reader to understand the rest of the test program.
3.1 Key Input and Output Parameters	3.2
3.2 Test Matrix	3.2
3.3 Test Methods and Uncertainties	3.2, 3.2.2, 5, 7
3.4 Test Procedures	3.2, 5, 7
3.5 Illustrations	Scattered throughout sections as applicable to the discussion.
3.6 Contingency Plans	3.2.3

3.7 Performance Objectives	Not applicable
3.8 How Testing Meets Customer Need	Customer needs are more completely defined in the Technical Task Plan (TTP) and will be satisfied by completion of the test objectives defined in the TTP and in Section 1.3.
4. SEQUENCE OF ACTIVITIES	4. SEQUENCE OF ACTIVITIES
5. SAMPLING AND DATA	5. MEASUREMENTS AND SAMPLE COLLECTION
5.1 Data Applicability to CERCLA Criteria	Not applicable at this point in the demonstration program.
5.2 Data Collection Techniques	Throughout Sections 3.2 and 5. Standard procedures are not described in detail but will follow the referenced procedures.
5.3 Sampling and Data Collection Procedures	Throughout sections 3.2 and 5. Standard procedures are not described in detail but will follow the referenced procedures.
5.4 Sampling and Analysis Requirements	Section 5
6. DOCUMENT CONTROL	6. DOCUMENT CONTROL
6.1 Data Documentation, Control, and Storage	6.1 Data Documentation, Control, and Storage
6.2 Test Plan Modifications	6.2 Test Plan Change Control
6.3 Document Control for Other Documents	6.3 Document Control for Other Documents
7. ANALYTICAL METHODS	7. ANALYTICAL METHODS. Standard procedures are not described in detail but will follow the referenced procedures.
8. DATA REDUCTION, VALIDATION, AND VERIFICATION	8. DATA REDUCTION, VALIDATION, AND VERIFICATION
8.1 Data Reduction Scheme	8.1 Data Reduction Scheme and in procedures referenced in Sections 5.3.1, 5.3.2, 5.3.3, and 7.
8.2 Data Validation	8.2 Data Validation and in procedures referenced in Sections 5.3.1, 5.3.2, 5.3.3, and 7.
8.3 Data Validation Responsibility	8.3 Data Validation Responsibilities

8.4 Acceptance Criteria	8.4 Acceptance Criteria for Test Data, especially Tables 8-1, 8-2, and 8-3.
9. QUALITY ASSURANCE	9. QUALITY ASSURANCE
9.1 Quality Level	9.1 Quality Level
9.2 Quality Control Methods	9.2 Quality Control Methods
9.3 Routine Procedures for Assessing Precision, Accuracy and Completeness	9.3 Routine Procedures, to the extent needed for this test plan.
9.4 Change Authorization	Section 6.2
9.5 Internal Audit/Surveillance System	Section 9.4
10. EQUIPMENT AND INSTRUMENTS	Sections 3, 5, 7, and 10
10.1 Equipment List	Sections 5, 7, and 10.1 (to the degree necessary for this test plan).
10.2 Equipment Range, Accuracy and Tolerance	Sections 5, 7, 8, and 10.2 (to the degree necessary for this test plan).
10.3 Calibration and Standardization Procedures	Sections 5, 7, 8, and 10.3 (to the degree necessary for this test plan).
10.4 Preventive Maintenance Schedule	Described in procedures referenced in Sections 5 and 7
10.5 Sensitivity to the Environment	Described in procedures referenced in Sections 5 and 7
11. SUPPLIES, UTILITIES AND FACILITIES	11. SUPPLIES, UTILITIES, AND FACILITIES, and as described in procedures referenced in Sections 5 and 7
12. HEALTH AND SAFETY	12. HEALTH AND SAFETY
13. RESIDUALS MANAGEMENT	13. RESIDUALS MANAGEMENT
14. REFERENCES	14. REFERENCES
15. APPENDICES	15. APPENDICES