

Poster Session 30 - Wednesday, February 28, 1996

Mercury Retorting of Calcine Waste, Contaminated Soils, and Railroad Ballast at the Idaho National Engineering Laboratory

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ABSTRACT

The Idaho National Engineering Laboratory (INEL) has been involved in nuclear reactor research and development for over 40 years. One of the earliest major projects involved the development of a nuclear powered aircraft engine, a long-term venture which used mercury as a shielding medium. Over the course of several years, a significant amount of mercury was spilled along the railroad tracks where the test engines were transported and stored. In addition, experiments with volume reduction of waste through a calcine process employing mercury as a catalyst resulted in mercury contaminated calcine waste.

Both the calcine and Test Area North wastes have been identified in Department of Energy Action Memorandums to be retorted, thereby separating the mercury from the various contaminated media. Lockheed Idaho Technologies Company awarded the Mercury Retort contract to ETAS Corporation and assigned Parsons Engineering Science, Inc. to manage the treatment field activities.

The mercury retort process entails a mobile unit which consists of four trailer-mounted subsystems requiring electricity, propane, and a water supply. This mobile system demonstrates an effective strategy for retorting waste and generating minimal secondary waste.

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SITE BACKGROUND

The Idaho National Engineering Laboratory (INEL), formerly the National Reactor Testing Station (NRTS), encompasses 2,305 km² (890 mi²), and is located approximately 32 km (20 mi) west of Idaho Falls, Idaho (Fig. 1). In 1949, the United States Atomic Energy Commission, now the Department of Energy (DOE), established the NRTS as a site for building and testing a variety of nuclear facilities. Since 1952, the INEL has also functioned as the storage facility of transuranic radionuclides and low-level radioactive waste. At present, the INEL supports engineering and operations efforts of DOE and other Federal agencies in areas of nuclear safety research, reactor development, reactor operations and training, nuclear defense materials production, waste management technology development, and energy technology and conservation programs. The DOE Idaho Field Office (DOE-ID), having responsibility for the INEL, designates authority to operate the INEL to government contractors. The primary contractor for DOE-ID at the INEL is Lockheed Idaho Technologies Company (LITCO), which provides managing and operating services to the majority of INEL facilities. The remedial design/remedial action contractor for LITCO at the INEL is Parsons Engineering Science, Inc., which provides complete remedial design and remedial action (RD/RA) services.

ORIGIN OF MERCURY CONTAMINATED MATERIAL

Calcine Material

In the late 1950's and early 1960's, research teams at the INEL conducted developmental work on the recovery of uranium from spent nuclear fuels and the subsequent treatment of the resulting wastes. Solutions from which the uranium had been extracted were calcined to reduce their volume and make them easier to handle and dispose. In various pilot studies, carried out at the Central Facilities Area (CFA) Chemical Engineering Laboratory at the INEL site, simulated aluminum clad fuels were treated, with mercury added as a catalyst in the calcining process. The calcined material and elemental mercury was disposed in a depression near the test facility and eventually covered with gravel. Through different mechanisms, the calcine waste was partially exposed to the elements. Subsequent investigations determined that the calcined material exhibited low-level radioactivity (from radioactive tracers, Cesium-137, Strontium-90, Ruthenium-106, and unidentified Uranium isotopes used during the calcine

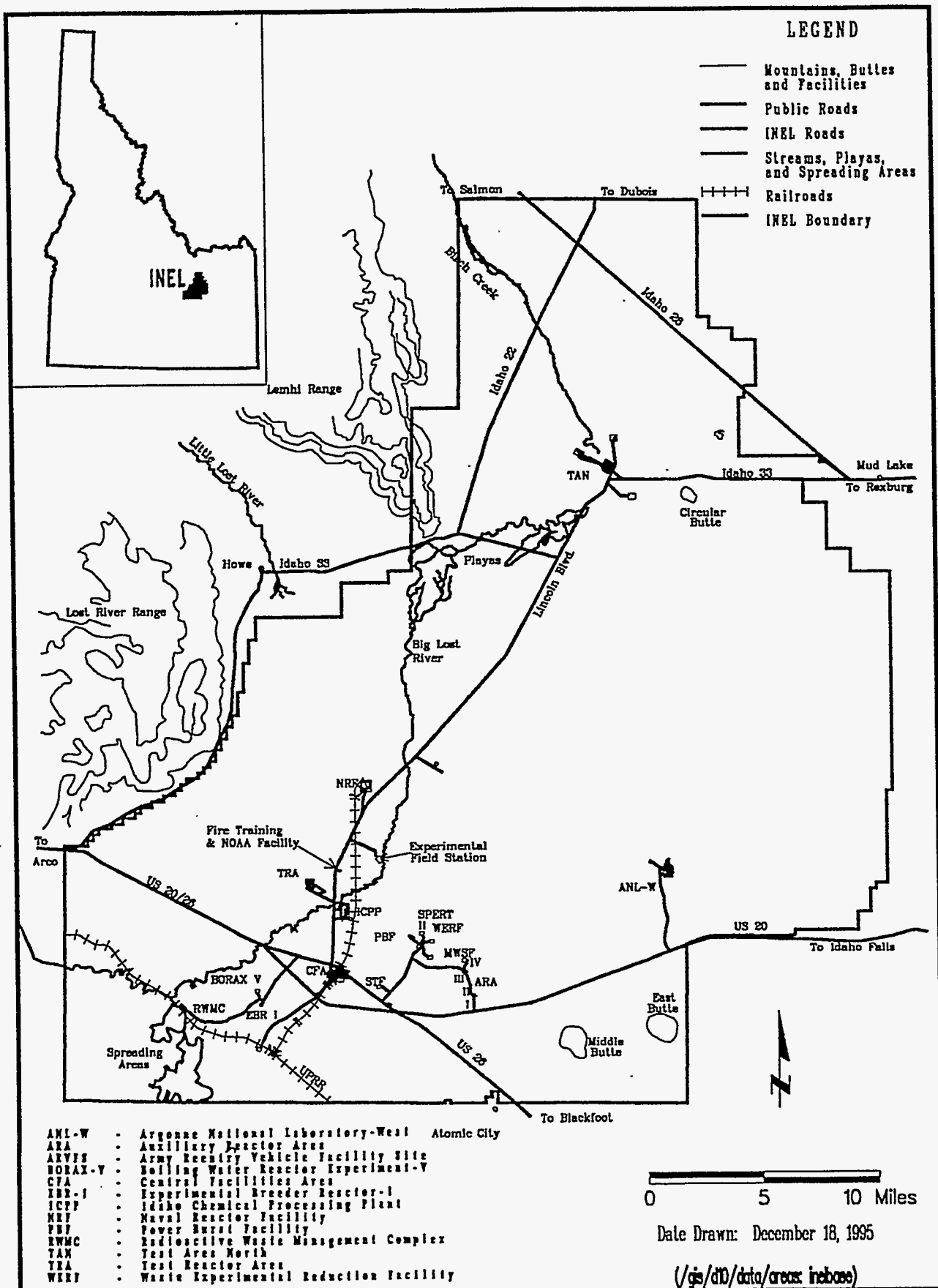


Figure 1-2. INEL Site Map.

(Place Fig. 1 here.)

Fig. 1
Location of INEL

experiments) and mercury concentrations above 260 mg/kg. The waste calcine and surrounding contaminated soil were retrieved and containerized for future treatment. In a fluidized-bed calciner, the calcined material was formed at temperatures between 400 and 500 degrees Celsius. Held at this temperature only long enough to drive off the water coming in with the feed, the material left a large percentage of the feed mercury in the calcine when the calcine cooled. Though the calcine is porous, the mercury had insufficient time to vaporize and migrate out of the calcined material. A significant portion of this mercury is still present in the calcine in the form of mercury oxide.

The selected remedial action will meet final concentration limits of less than 0.2 mg/L mercury as determined by the Toxicity Characteristic Leaching Procedure, Environmental Protection Agency (EPA) analysis Method 1311, and less than 80 mg/kg total mercury as determined by EPA Method 7470/7471 (SW846).

Test Area North Material

In addition to the calcine waste, a second waste stream will be treated. This waste stream consists of mercury contaminated soil and railroad ballast contaminated by a large spill of elemental mercury at the INEL's Test Area North (TAN) in 1958. This mercury contaminated material was excavated and containerized in 1994. Sample results indicated that the material exhibited low level radioactivity (Cesium-137 and Strontium-90) and mercury concentrations above 450 mg/kg. The radioactive isotopes, Cesium-137 and Strontium-90, are the result of radioactive storage in the immediate vicinity.

The selected remedial activity will meet final concentration limits of less than 0.2 mg/L mercury as determined by the Toxicity Characteristic Leaching Procedure, Environmental Protection Agency (EPA) analysis Method 1311, and less than 4 mg/kg total mercury as determined by EPA Method 7470/7471 (SW846).

MERCURY RETORT SYSTEM

ETAS Corporation is not only the operator of the mercury retort system, but ETAS developed, designed, and fabricated the mercury retort system as well.

System Components

The mercury retort process entails a mobile unit which consists of four trailer-mounted subsystems with multiple components or units in each subsystem (Fig. 2). The four subsystems are:

- Feed System
- Retort Main System
- Vapor Recovery System
- Material Discharge System

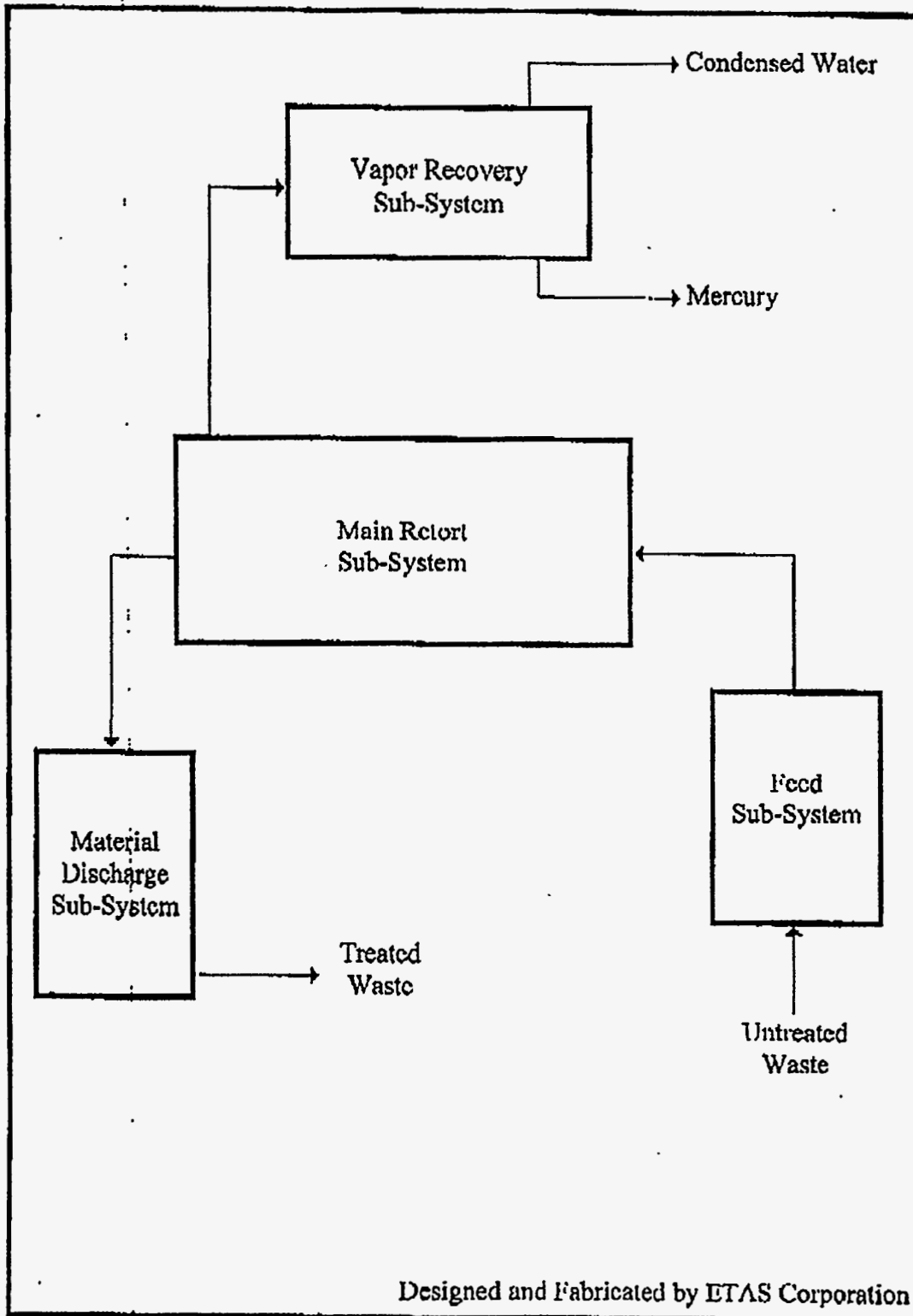


Figure 2. Mercury Retort System Process Flow Diagram

(Place Fig. 2 here)

Fig. 2
Mercury Retort System Process Flow Diagram

Feed System

Vacuum Unit

A vacuum unit was initially used to transfer material from the drums and boxes into the retort main system. The vacuum unit, an off-the-shelf manufactured system, is equipped with integral dust controls, including a multi-stage cyclone and a HEPA filter. A slide gate between the vacuum unit and the retort provided the necessary seal between the units.

The vacuum system was designed to minimize blowing dust during transfer of dry material from the waste containers. As treatment progressed, monitoring showed that almost all the material was at least damp and much was very wet, producing severe caking in the vacuum unit. Subsequently, an auger feed was tried, and finally a conveyor belt system installed. After the material was shoveled from waste containers into a hopper at ground level, a fully enclosed conveyor belt dumped the material onto a slide gate. The slide gate opened periodically to feed the material into the retort. The conveyor enclosure minimizes blowing material. The slide gate seals the feed end of the retort and provides for circulation of gases through the retort and into the vapor recover system.

Retort System

The Retort Main System consists of the following components/units:

- The Retort Chamber
- Burners and Mechanical Controls
- Gas Supply Piping Components
- Burner Control Cabinet
- Power and Motor Control Cabinet

Retort Chamber

The Retort Chamber is a heated assembly, which consists of a rotating process tube mounted axially inside a refractory lined shell. The rotating drum is lined with curved vanes, which both propel material forward and mix the material as the drum rotates. This not only conveys the material, but assures that the material is heated quickly and evenly. The unit rotates from 4 to 25 rpm, which allows a material transfer rate of 0.54 to 4.51 m³ (0.7 to 5.9 yd³) per hour. Constructed entirely of 304 steel, the rotating drum sits in the refractory lined outer tube chamber, which houses the burners. The curved shape of this chamber directs the burner flames around the tube for efficient heating.

Burners & Mechanical Controls

The burners essentially fire horizontally under the process tube for minimal flame impingement on the tube. The radiant heat of the flame and the convective heat of the hot combustion products heat the tube, which transfers heat to the product traveling through the tube.

Although the burners can be individually started and stopped, the burner firing rates are controlled by three process tube zone temperature controllers, with each controller driving three burners. ETAS has included several automatic features to provide remote and dual temperature controller set points, and will provide "cutback" logic in case stack temperatures become too high.

Rated for 1.0 MBTU/H firing propane, each burner consists of an integral fan housing directly coupled to the fan motor, gas burner and blast tube, gas pilot/igniter assembly, flame detector port, and viewport. The burners utilize modulating motors to control firing rates and fuel/air ratios. The system is equipped with temperature controllers for each of the three process tube zones; each controller will provide a control signal to regulate the modulating motors on all three burners for that zone.

Gas Supply Piping Components

Propane to the main fuel and pilot on each burner is turned on and off by the burner safety shutoff valves, with the fuel rates being controlled by the regulators and the main fuel modulating control valve. All safety shutoff valves are of the automatic type. The automatic shutoff valves provide for automatic shutdown of the fuel feed during certain conditions, and further provide for a single button shutdown during any emergency situations.

Burner Control Cabinet

The burner control cabinet is an air purged, free standing cabinet containing all burner system controls, indicators, and alarms.

The entire system is designed for maximum burner operating flexibility and maximum user friendliness. The system utilizes individual flame programmers for each burner, each with its own status indicator visible through a window on the cabinet door. ETAS included one enhanced display module designed to automatically switch to display the operating burner, providing enhanced sequence and alarm information for that particular burner. In addition, the system includes extensive alarm logic and indications for virtually all operating conditions, as well as main system purge controls and indicators.

Power and Motor Control Cabinet

This cabinet is an air purged, free standing cabinet, containing circuit breakers and motor starters for all nine unit motors, all nine burner motors, and control power circuit breakers for the burner control cabinet. Main 480 volt 60 cycle 3 phase (480/60/3) power and all nine unit motors can be controlled by the respective start/stop push buttons, and are indicated by the respective lights mounted on the cabinet door. The primary side of these transformers are protected by two-pole circuit breakers. The main logic section and each of the nine burner sections are protected by individual single-pole circuit breakers.

Vapor Recovery System

The vapor recovery system (VRS), having its own control cabinet, is a stand-alone system designed specifically for the removal of mercury. The entire Vapor Recovery process is performed under a vacuum created by a blower, which pulls the vapor stream through the VRS and pushes the final vapor stream out through the carbon canisters. This vacuum assures that no pressure can build in the vapor recovery system. Pressure buildups have been shown to cause leaks in retort operations without vacuum assisted vapor recovery systems.

The VRS consists of three main removal sections, followed by carbon canisters. These sections are the Spray Scrubber, the Sieve Tray Scrubber, and the Vapor Separator.

Spray Scrubber

Material first passes through the spray scrubber, a direct contact heat exchanger which condenses the bulk of the vapors. This scrubber is powered by process water, which in turn is cooled by an indirect heat exchanger linked to a cooling tower.

Sieve Tray Scrubber

The Sieve Tray Scrubber condenses any remaining condensable vapors which escape condensation in the Spray Scrubber. The Sieve Tray Scrubber is also a direct contact heat exchanger, linked to the same cooling tower and indirect heat exchanger as the Spray Scrubber. Condensed vapors from both scrubbers are collected in a common surge tank, where baffles at the bottom of the tank capture mercury and particulate matter from the process water stream.

Vapor Separator

The vapor separator, the last piece in the system, provides a mist eliminator and a low vapor velocity zone to collect mist and return it to the surge tank.

Product Cooler System

An airlock provides a vapor seal between the retort and the material discharge system.

Airlock

The airlock is a rotary eight-vane unit, which provides a high-quality seal against air leaks. As the airlock rotates (at approximately 40 RPM), material passes via the rotating vanes from one end of the airlock to the other. The unit has a 1.5 HP motor and uses sizable gear reducers to achieve the 40 RPM working speed.

Product Loading System

The material discharge system cools the treated material while moving the material from the retort into storage boxes. The cooling and transfer is accomplished by three totally enclosed screw augers, two of which have coolant passing through jackets. This system shares a cooling tower and refrigeration with the Vapor Recovery System.

SYSTEM PERFORMANCE

Production Rates

The retort system has proven effective at meeting the treatment standards. Production rates have not reached the maximum potential of the system's capacity due to site specific issues. Feed material high moisture content in conjunction with freezing temperatures, size gradation of the railroad ballast relative to the material handling system design, and foreign objects, such as railroad spikes and construction debris, have all been contributing factors to the production rates contained in the feed material.

Treatment Results

Based on more than 20 samples taken and analyzed for total mercury and/or TCLP, the retort system is demonstrably effective in removing mercury from various waste streams, as summarized in Table I.

(Place Table I here.)

Table I - Treatment Summary

Waste Stream	Batch No.	Total Mercury (mg/kg) 1st Sample ^a	Total Mercury (mg/kg) 2nd Sample ^b	TCLP (mg/l)
TAN	1	<3.0	na ^c	<0.002
TAN	2	5.9	1.3	<0.002
TAN	3	1.3	na	<0.002
TAN	3 Duplicate	2.7	na	<0.002
TAN	4	8.9	0.6	<0.002
TAN	5	4.0	na	0.068
TAN	6	6.0	1.0	<0.002 ^d
TAN	7	<3.0	na	<0.002
TAN	8	6.1	1.0	<0.002 ^d
TAN	9	3.0	na	<0.002
TAN	10	7.3	4.0	<0.002 ^d
TAN	Rinseate	na	na	<0.002
Calcine	1	23.7	na	RP ^e
Calcine	2	4.6	na	RP
Calcine	3	41.2	na	RP
Calcine	4	26.3	na	RP
Calcine	5	7.8	na	RP

^a Sample collection may be biased towards fines.

^b Sample included coarse grained fraction.

^c na = not analyzed

^d TCLP results from 2nd sample.

^e RP = results pending

CONCLUSIONS

Material Handling Considerations

Subcontractors must evaluate the feed stock and determine the appropriate material handling equipment needed to handle the feed material and all expected worst case conditions. A proactive design that addresses the above concerns may require a greater initial capital cost, but consistently proves less expensive in the long run when compared to the costs of frequent mini-design changes occurring as situations arise.

Cold Weather Operations

Manual labor operations and work activities in unprotected areas in the winter may result in hypothermia or exhaustion caused by working in heavy clothing and respirators. Equipment, particularly wetted systems, must be protected from freezing, especially during non-operating periods. Employee well-being is directly proportional to production and every effort must be made to account for the expected climate during the project execution.

DOE Contracting

Subcontracts let at DOE facilities in the future will rely more heavily on fixed price lump sums or unit rates for fixed quantity contracts. These contracts will require subcontractors to incur more initial financial risk: the bulk of their payment will be received only after their services have been both completed and certified as meeting all performance specifications.

This requires bidders to ask for more clarification so that they are fully aware of the site conditions, as change orders and overruns are being tolerated less and being funded even less.

If conditions are accepted by the subcontractor, then it is assumed by the contractor that the subcontractor is comfortable with the site conditions and has bid the project accordingly.