INEEL/CON-99-00330
PREPRINT

IDAHO NATIONAL ENGINEERING & ENVIRONMENTAL LABORATORY

Completion of the INEEL's WERF Incinerator Trial Burn

C. Branter
D. Conley
S. Corrigan
D. Moser

May 10, 1999 – May 14, 1999

1999 International Conference on Incinerator and Thermal Treatment Technologies

LOCKHEED MARTIN

COMPLETION OF THE INEEL'S WERF INCINERATOR TRIAL BURN

Curtis Branter, Dennis Conley, Shannon Corrigan, David Moser
Lockheed Martin Idaho Technologies Company

ABSTRACT

This paper describes the successes and challenges associated with Resource Conservation and Recovery Act (RCRA) permitting of the Idaho National Engineering and Environmental Laboratory's (INEEL) Waste Experimental Reduction Facility (WERF) hazardous and mixed waste incinerator. Topics to be discussed include facility modifications and problems, trial burn results and lessons learned in each of these areas. In addition, a number of challenges remain including completion and final issue of the RCRA Permit and implementation of all the permit requirements.

The WERF incinerator began processing beta/gamma-emitting low-level waste (LLW) in September 1984. The first RCRA trial burn for the WERF incinerator was conducted in 1986 and in 1989 WERF began processing mixed (hazardous and low-level radioactive) waste (MLLW). On February 14, 1991, WERF operations were suspended to improve operating procedures and configuration management. On July 12, 1995, WERF reinitiated incineration of LLW and on September 20, 1995, WERF resumed its primary mission of incinerating both INEEL and other Department of Energy (DOE) complex MLLW. MLLW incineration is proceeding under RCRA interim status.

A second trial burn was initiated in July 1997 and was completed in August 1998. The purpose was to demonstrate compliance with the current regulatory guidance and performance capabilities of recent equipment and operational modifications to the incinerator. The trial burn consisted of four low-temperature and six high-temperature test burns that successfully established a flexible operating envelope. A flexible operating envelope is necessary to process the wide variety of MLLW that exists in the DOE complex. Sampling and analyses were performed to evaluate destruction and removal efficiency (DRE), dioxin/furan, carbon monoxide (CO), hydrogen chloride (HCl), metals, particulate, and total organic emissions, volatile and semivolatile products of incomplete combustion, and polychlorinated biphenyls. Results from the trial burn demonstrated that the operating conditions and procedures will result in emissions that are satisfactorily protective of human health, the environment, and are in compliance with Federal and State regulations.

INTRODUCTION

The WERF is located at the INEEL. It is a versatile mixed low-level and low-level radioactive waste treatment facility that has been in operation since August 1982. The purpose of the WERF is to treat, reduce the volume, and enhance the form of MLLW and LLW.

The WERF employs waste characterization, repackaging, incineration, stabilization, sizing, macroencapsulation, and compaction. The incinerator has been processing beta/gamma LLW and MLLW since September 1984. The State of Idaho, the Department of Energy, and other federal agencies regulate WERF incinerator operation. The primary regulations governing incinerator operations include the RCRA and the Clean Air Act (CAA). The WERF has a State of Idaho Air Quality Permit To Construct that establishes limitations on incinerator emissions and operations and identifies the required emissions monitoring. Mixed waste operations are primarily regulated by the RCRA.

The WERF incinerator is a Model 1000 TLE, dual chambered, controlled-air incinerator. The incinerator has a thermal capacity of 6.5 MBtu/hr. A schematic of the incinerator and air pollution control system is shown in Figure 1.

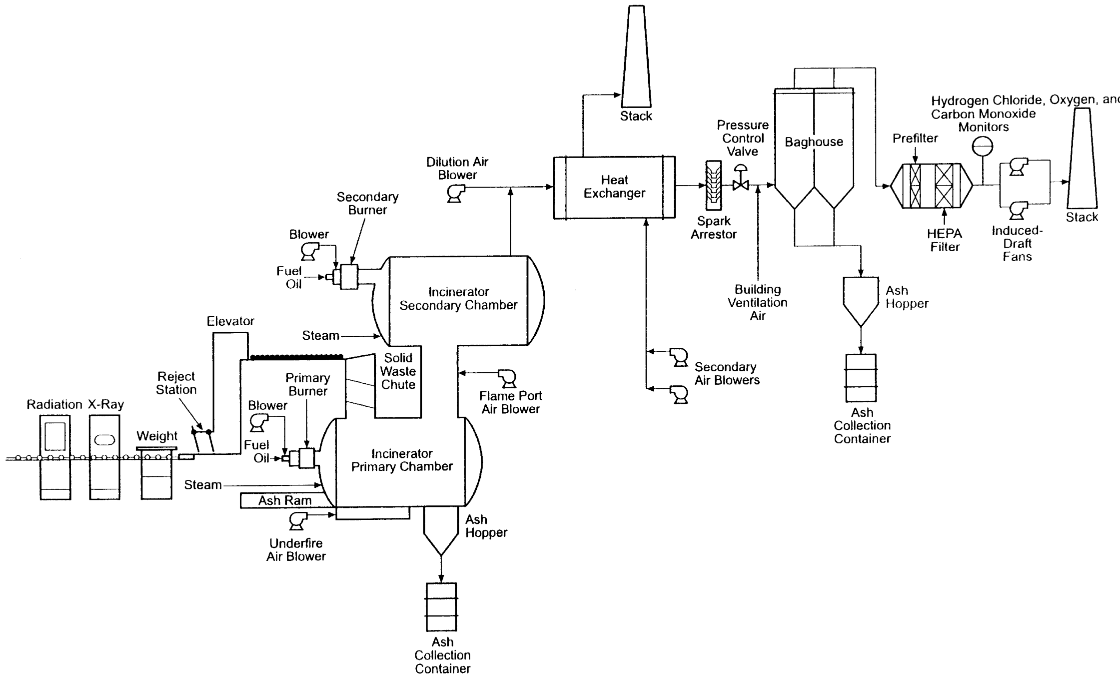

FIGURE 1. Schematic of the WERF incinerator, feed system, and air pollution control system.

Incineration achieves 200:1 or more volume reduction while detoxifying and homogenizing solid wastes into a form (ash) suitable for stabilization and disposal. The waste that is burned in the WERF incinerator consists primarily of wood, paper, cloth and plastics. Additional waste feed includes small quantities of solid and liquid combustible mixed wastes and aqueous mixed wastes. The MLLW feed for the incinerator comes in various containers meeting the storage facility waste acceptance criteria and must be repackaged in cardboard boxes to meet incinerator feed requirements. Both combustion chambers are equipped with auxiliary fuel oil fired burners to preheat the system and maintain the temperatures that are required during waste processing operations. The typical operating temperature is 870 to 1150^{o}C (1600 to 2100^{o}F) in the primary combustion chamber (PCC) and 980 to 1150^{o}C (1800 to 2100^{o}F) in the secondary combustion chamber (SCC).

After the minimum temperatures and all other operating conditions have been achieved, solid waste is gravity-fed to the primary chamber through the solid waste feed chute. In the primary chamber, a substoichiometric environment is maintained by controlling the introduction of air through the underfire air ports, located in the hearth. By maintaining a substoichiometric environment in the primary chamber, volatile materials can be driven off in a controlled manner and maintaining a substoichiometric environment in the primary chamber maximizes particulate retention. As the volatile materials enter the secondary chamber they pass through the flameport region where additional air is added to provide an excess air environment. At five MBtu/hr of heat release with 100% excess air, the secondary chamber provides approximately 2 seconds residence time at 1150^{o}C (2100^{o}F).

The incinerator offgas system is a dry mechanical filtering system employing air mixing, a shell and tube heat exchanger for cooling, and a baghouse and High Efficiency Particulate Air (HEPA) filters to remove particulate matter. The baghouse employs fabric filter "bags" to capture particulate entrained in the offgas. Baghouses are recognized in the industry as the most efficient means of particle removal available, collecting more than 99%

of all particulate greater than 0.5 microns in diameter. Following the baghouse is a stage of HEPA filters. The HEPA filters are capable of removing 99.97% of all particulate in the range of 0.1 to 0.3 microns in diameter. This degree of offgas cleanup maintains radioactive emissions at less than 74,000 Bq/yr (2uCi/yr).

As of March 1999, approximately 1.1 million kg (2.4 million lbs.) of waste has been burned, of which approximately 209,000 kg (460,000 lbs.) was MLLW. The incinerator is normally operated once a month in 10 to 20-day campaigns of around-the-clock operation. Listed and characteristic MLLW streams are normally incinerated in separate burn campaigns to minimize the amount of listed waste ash generated.

The WERF incinerator has processed, in addition to INEEL LLW and MLLW, MLLW from the following sites.

- Los Alamos National Laboratory (New Mexico)
- Paducah Gaseous Diffusion Plant (Kentucky)
- Pantex (Texas)
- Sandia National Laboratories (California and New Mexico)
- United States Navy (California, Connecticut, Hawaii, New York, Pennsylvania, South Carolina, Virginia, and Washington)

Processing wastes from the following sites is planned for the near future.

- Argonne National Laboratory (Illinois)
- Hanford (Washington)
- Lawrence Berkeley National Laboratory (California)
- Portsmouth Gaseous Diffusion Plant (Ohio)
- Rocky Flats (Colorado)

When MLLW incineration was restarted in 1996 the RCRA Part B permit application process that was started in 1991 was reactivated. This process included revision of the Part B permit application and resubmittal to the State of Idaho Division of Environmental Quality (DEQ). Included in this application was the Trial Burn Plan that identified the details and schedule for the RCRA Trial Burn.

The RCRA Trial Burn was designed to demonstrate compliance with the performance standards in the Idaho law and the current Environmental Protection Agency (EPA) incinerator guidance. The trial burn was conducted to obtain a RCRA operating permit with a single set of operating parameters used for burning a broad range of waste. To accomplish this, the trial burn was designed to represent the worst-case mix of wastes and operating conditions the incinerator could encounter during normal operation. The current EPA risk assessment guidance requires a low-temperature test and a high-temperature test. The low-temperature test is designed to demonstrate maximum organic emissions and the high-temperature test is designed to demonstrate maximum metal emissions. The RCRA Trial Burn was completed in August 1998. The DEQ RCRA permitting personnel are currently reviewing the RCRA Trial Burn Report.

OPERATIONAL AND FACILTY MODIFICATIONS

Ventilation Changes

The original incinerator offgas design drew flameport air from outside the building and first cooling air from the incinerator room. This design allowed any incompletely combusted organic materials that may have escaped through the incinerator feed hatch to enter the offgas system past the secondary chamber. After discussing this configuration with DEQ permitting personnel, it was decided to modify this design. The new design draws flameport air from a hood over the feed chute and first cooling air from outside the building. This forces any incompletely combusted organic materials to pass through the secondary chamber and be destroyed.

Heat Exchanger Outlet Temperature

During the July 1997 high-temperature trial burn dioxin/furan emissions were higher than expected. The average primary combustion chamber temperature and the average heat exchanger outlet temperature were identified as the most likely parameters contributing to the high-dioxin/furan emissions. These parameters were designed into a test matrix used in the February 1998 mini-burn. Figure 2 illustrates the effects of these two parameters independently and in combination by comparing the test results relative to low and high temperature conditions.

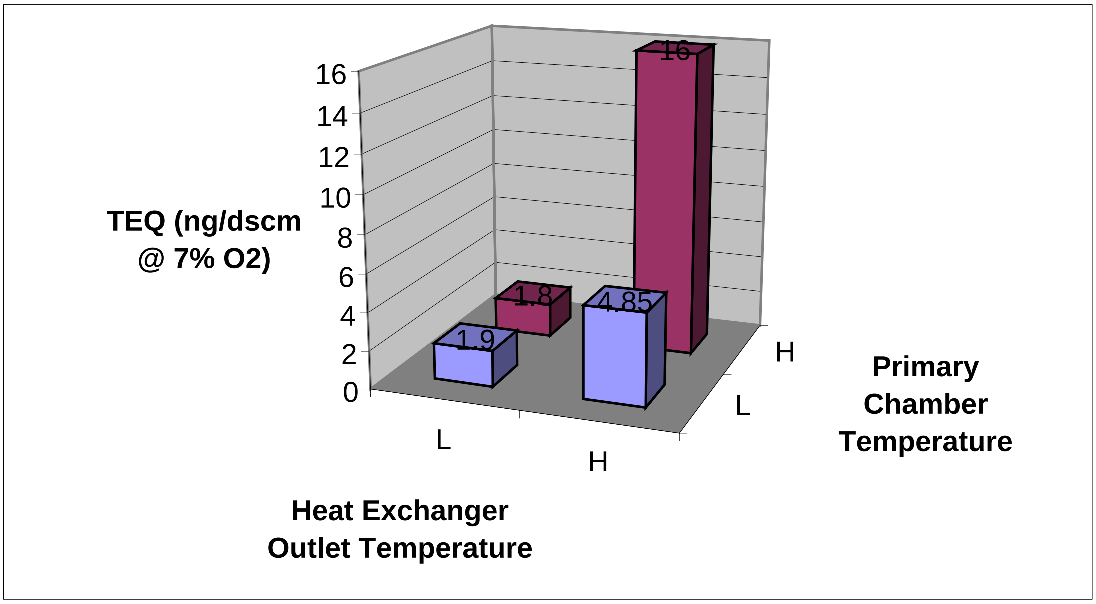

FIGURE 2. TEQ Concentration vs. Heat Exchanger Outlet Temperature and Primary Chamber Temperature.

The toxic equivalent (TEQ) values of 1.9 and 1.8 indicate that at a low heat exchanger outlet temperature, the primary chamber temperature has no effect on dioxin/furan emissions. However, comparing TEQ values of 1.9 to 4.85 and 1.8 to 16 strongly indicates that the heat exchanger outlet temperature, independent of primary chamber temperature, affects dioxin/furan emissions levels.

Therefore, during the high-temperature trial burn in August 1998 the average heat exchanger outlet temperature was maintained as low as possible at 337^{o} C (638^{o}F). The average TEQ values were 6.2 ng/dscm, down from 42.7 ng/dscm during the July 1997 high-temperature trial burn.

SCC Residence Time Improvement
One of the efforts to improve incinerator DRE performance over that obtained in the July 1997 high-temperature trial burn focused on increasing gas residence time in the SCC while maintaining other SCC parameters, such as oxygen concentration, within desired ranges. As suggested by the following example, adjusting one process parameter to a more desirable value can result in another process parameter changing to a less desirable value in response.

The lower the flow of gas through the SCC, the higher the residence time. In general, the higher the residence time, the better the DRE performance. The SCC total gas flow is comprised primarily of the gaseous products of waste combustion, products of combustion from the SCC auxiliary burner, and excess air. Lowering any of the three flow rates would reduce the SCC total gas flow rate, which would provide a higher residence time. Reducing the flow rate of products of waste combustion would require decreasing the waste feed rate. Since it is desired instead to maximize the waste feed rate, this option was not pursued. Reducing the flow rate of products of combustion from the SCC auxiliary burner would require a change in operations to decrease the amount of auxiliary heat needed to maintain the desired temperature in the SCC. This could be accomplished if less air was introduced via the flame port, which is the third option for reducing total SCC gas flow rate. While reducing flame port air flow rate would increase residence time directly through reduced ingress of air and indirectly through lowered average output of the SCC auxiliary burner, the average oxygen concentration in the SCC would also be lowered – perhaps to a level at which acceptable DRE performance could not be achieved.

An incinerator test using surrogate waste was conducted to evaluate the feasibility of reducing the flame port air flow rate. A proper understanding of the conduct and results of the test requires an appreciation of the operation of the flame port air flow rate control damper. When a waste feed box is first introduced into the PCC, it gives off burned and unburned volatile matter at a relatively high rate, so a corresponding high rate of flame port air addition is needed. Once most of the box and contents have been burned to near completion, less air is needed. However, since during a burn campaign, organic matter mixed with ash in the PCC continues essentially throughout the campaign to volatilize, continuous addition of flame port air is needed to ensure satisfactory combustion performance in the SCC. So, the flame port air controller is operated at two settings – a maximum flow established shortly before a waste box is fed and for a few minutes thereafter and then a minimum flow in between waste box feeds.

The testing, which was conducted with surrogate waste, involved varying the maximum and minimum flame port air flow rates and observing the resulting process conditions. Changes to the flame port air flow were effected by adjusting mechanical stops on the flame port air flow control damper. The testing showed that, with the lower damper position set slightly more open and the upper damper position set significantly more closed, the SCC flow could be significantly lowered, thus increasing residence times, while maintaining SCC oxygen levels within a reasonable band. The SCC residence times achieved in the surrogate tests were significantly longer than those observed in the July 1997 high-temperature portion of the Trial Burn. The SCC oxygen concentrations seldom fell to less than 5% and usually ranged between 7% and 11%. These higher residence time conditions were then used in subsequent burn campaigns including the successful August 1998 high-temperature trial burn.

TRIAL BURN WASTE FEED COMPOSITION

Table 1 shows the typical contents of a burn box used as feed during the trial burn. The trial burn feed was a blend of actual waste and simulated waste formulated to represent worst-case blends of difficult-to-destroy waste, ash content, volatile matter content, chlorine content, and metals. A subcontractor prepared the principle organic hazardous constituent spikes and metal spikes. The waste liquid and virgin oil, each of which was absorbed onto ground corn cobs, and diatomaceous earth were placed into burn boxes before the trial burn began. Final preparation of a given waste feed box was completed during the trial burn just before the box was scheduled to be fed. Final preparation included verifying the weights of spikes and placing them in the burn box, and finally adding either virgin oil or water absorbed onto ground corn cobs depending on the temperature of the PCC. If the PCC temperature was higher than desired, water was added or if the PCC temperature was at or below the desired temperature, oil was added.

TABLE I. Trial Burn Waste Feed Composition

Constituent	Low Temperature (kg/box)	High Temperature (kg/box)
Cardboard	1.13	1.13
Ground Corn Cobs	6.08	9.34
Plastic	1.86	1.99
Diatomaceous Earth	2.61	2.43
Water	8.27	0
Fuel Oil	0	4.94
Aqueous Waste	2.27	1.80
Chlorobenzene	0.17	0.17
Carbon Tetrachloride	0.17	0.17
Copper Chloride	0.01	0.01
Cadmium	0	0.12
Sodium Chromate	0	0.39
TOTAL	22.57	22.49

TRIAL BURN RESULTS

The objective of the trial burn was to demonstrate compliance with the current hazardous waste incinerator guidance and the WERF Trial Burn Plan. A goal during the entire trial burn was to obtain the largest operating envelope possible, because this would allow WERF maximum flexibility to operate once a permit is issued. To ensure compliance with hazardous waste incinerator guidance, a group of incinerator parameters are classified as Automatic Waste Feed Cutoffs (AWFCs). The primary function of the AWFC system is to prevent the feeding of waste when key incineration conditions fall outside the predetermined range. Although 21 AWFC parameters are expected when the RCRA permit is issued, only the results of the following AWFC parameters will be addressed:

- Minimum and maximum temperature in the primary chamber
- Minimum and maximum temperature in the secondary chamber
- Maximum heat exchanger outlet temperature (determined from high-temperature test)
- Residence Time of offgas in the secondary chamber
- Maximum baghouse inlet temperature (determined from high-temperature test)
- Maximum waste feed rate

In the low and high temperature tests, only three valid test runs are required to obtain a RCRA permit. Although only three runs are required, WERF decided to perform four runs during the low-temperature test and six runs during the high-temperature test. The decision to try more than 3 runs was based on several factors: 1) the analytical lab may accidentally lose a sample during analysis, 2) incineration parameters were not acceptable for establishing permit conditions and 3) test run was unable to be completed due to high primary chamber temperature (caused test run to be canceled for that day). In Table II are the AWFC parameter results, along with the destruction removal efficiency for chlorobenzene and carbon tetrachloride and the dioxin/furan toxic equivalent concentration.

TABLE II. Trial Burn Results

Summary of Low-Temperature Test Parameters

Parameters	Run 1	Run 3	Run 4	Average (Runs 1,3,4)	Permit Target
Primary Chamber Temperature					
Rolling Average (°C)	906	881	889	892	899
Instantaneous (°C)	884	860	863	869	871
Secondary Chamber Temperature	984	980	989	984	954
Rolling Average (°C)	936	938	944	939	927
Instantaneous (°C)					
Waste Feed Rate (kg/hr)	181	180	180	181	181
Residence Time					
Minimum (sec)	1.35	1.25	1.34	1.25	NA
Average (sec)	2.37	2.19	2.35	2.30	2 seconds
Destruction and Removal Efficiency, %					
Chlorobenzene	>99.9996	>99.9995	>99.9995	≥99.9985	≥99.99
Carbon tetrachloride	>99.9988	>99.9994	>99.9993	≥99.9992	≥99.99
Dioxin/Furan					As low as possible
Total toxic equivalent (ng/dscm @7% O_2)	6.1	4.3	3.7	4.7	

Summary of High-Temperature Test Parameters

Parameters	Run 3A	Run 4	Run 5	Average (Runs 3A,4,5)	Permit Target
Primary Chamber Temperature					
Rolling Average (°C)	1112	1109	1126	1116	1121
Instantaneous (°C)	1152	1151	1161	1154	1188
Secondary Chamber Temperature					
Rolling Average (°C)	1118	1123	1144	1128	1135
Instantaneous (°C)	1153	1156	1184	1164	1204
Waste Feed Rate (kg/hr)	177	178	178	179	181
Residence Time					
Minimum (sec)	1.55	1.60	1.62	1.55	NA
Average (sec)	2.53	2.55	2.68	2.57	2 seconds
Heat Exchanger Outlet Temperature					
Rolling Average (°C)	338	339	333	337	329
Instantaneous (°C)	346	347	341	345	357
Baghouse Temperature					
Rolling Average (°C)	197	206	201	201	202
Instantaneous (°C)	230	229	217	230	227
Destruction and Removal Efficiency, %					
Chlorobenzene	≥99.9985	≥99.9984	≥99.9987	≥99.9985	≥99.99
Carbon tetrachloride	≥99.9981	≥99.9984	≥99.9987	≥99.9984	≥99.99
Dioxin/Furan					As low as possible
Total toxic equivalent (ng/dscm @7% O_2)	6.9	6.1	5.4	6.2	

Distributed Control System

To comply with 40 CFR 264.347 “Monitoring and Inspections” requirements, WERF was required to install a means of continuously monitoring incineration parameters as identified in the RCRA Part B Permit. A Distributed Control System (DCS) was installed to provide continuous real-time monitoring, process and archiving of the process parameters associated with the WERF incinerator control and operational instrumentation. The operators station is a Sun Microsystems Ultra 1 Workstation running a Solaris 2.5 (UNIX) operating system. The DCS application runs on the workstation under LabVIEW 5.01 (data acquisition and control application development environment). Process parameters are presented to the operator in a graphical display that closely resembles the layout of the WERF incinerator. Process values are displayed numerically in the location on the graphic that matches the actual location of the instrument. In addition, parameters can be selected for a time-based trend plot. The LabVIEW application communicates directly with the acquisition hardware, provides the required averaging algorithms, archives the data at the appropriate intervals, and initiates AWFCs when permit parameter is exceeded.

An additional requirement of 40 CFR 264.347 is that all AWFC systems and associated alarms must be tested at least weekly to verify operability. To comply with this requirement, an additional program was written for the DCS software to allow the operator to perform an AWFC test prior to commencing feed of MLLW and every week during an incineration campaign. The
AWFC parameters that require continuous monitoring include, chamber temperatures, primary chamber pressure, CO emissions, combustion gas velocity indicator (indication of residence time), pressure differential across roughing and HEPA filters, baghouse inlet temperature, heat exchanger outlet temperature, secondary chamber oxygen content, and waste feed rate. The DCS will also calculate and record the CO emissions, corrected to 7% oxygen, and the calculated offgas flow rate parameter.

WHAT NEXT

The current RCRA Part B Permit Application for incineration was submitted to the DEQ in March 1997. The Trial Burn was completed in August 1998 and the report submitted to the DEQ in December 1998. The DEQ permitting personnel are in the process of reviewing these documents and preparing for the next steps in the permitting process. These steps include public hearings, identifying exact operating limits, and generating the final permit. In addition, the DEQ is considering combining the part of the RCRA storage permit application that directly supports incineration with the incineration permit application. This will require a revision to the currently submitted application.

New emission standards reflecting the performance of maximum achievable control technologies (MACT) have been proposed for increased protection to human health and the environment. A study was undertaken to determine the technical feasibility of upgrading the WERF to meet the offgas emissions limits proposed in the MACT rule. Additional objectives of this study were: (1) ensuring that a market exists for MLLW treatment at the WERF and (2) considering the possibility for broadening the WERF waste acceptance criteria.

Four offgas treatment options were considered, which if installed, would enable the WERF to meet the anticipated MACT emissions limits for dioxins/furans, HCl, and mercury (Hg). Each option was assessed in terms of technical feasibility, relative cost, physical requirements, and the impact on the WERF waste acceptance criteria.

If the WERF incinerator is to continue operation, the facility must be MACT compliant within three years of the date the final rule is issued. This three-year period includes the time necessary for performance testing and certification of compliance. Upgrade options costing more than $5 million were not considered further because their funding would require congressional approval and would probably take longer than the three years available.

The chosen option consists of a partial-quench evaporative cooler with dry sorbent injection for HCl removal followed by sulfur-impregnated activated carbon bed for Hg control. The partial-quench cooler is designed to rapidly cool the gas exiting the secondary combustion chamber to minimize dioxin/furan formation. Dry sorbent injection of an alkali reagent into the offgas is recommended for HCl control. The alkali reacts with the HCl to form a salt, which will be captured with the flyash in the baghouse. A design HCl removal efficiency of 97.2% allows feeding 9 kg/h (20 lbs./h) of chlorine to the incinerator. The sorbent feed rate can be adjusted to achieve the desired removal efficiency. A fixed bed of sulfur-impregnated carbon was conservatively sized for a total Hg removal capacity when feeding 10 g/h Hg to the incinerator. An added benefit for using carbon adsorption is that the activated carbon will also capture a large fraction of any residual dioxin/furan emissions in the offgas.

A review of mixed waste databases shows that approximately 5,000 m^3 of waste is available for treatment at the WERF in the next five years. An additional 5000 m^3 is expected to be available for WERF treatment through 2010. This figure does not include the significant waste volume form the other DOE incinerator sites if they are not upgraded to meet the proposed MACT rule. Based on average capacities there is enough waste within the DOE system that has been approved for WERF incineration to operate WERF at capacity for at least ten years. This waste inventory is independent of the MACT compliance status for the other DOE MLLW incinerators.

Since the proposed enhancements to the WERF air pollution control system removes offgas pollutants more efficiently than the current process, the WERF waste acceptance criteria can be expanded to allow more waste with higher contaminant concentrations to be treated. Additionally, if a minimum gas residence time of two seconds in the secondary combustion chamber can be maintained, polychlorinated biphenyls (PCBs) can be treated. Since PCBs are regulated under the Toxic Substances Control Act (TSCA), a TSCA permit would be required before PCB incineration could occur. Preliminary calculations indicate that this is possible.