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Innovative Technology
Summary Report

Portable Tritium Cleanup Cart

Deactivation and Decommissioning
Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

Portable Tritium Cleanup Cart

OST/TMS ID 2974

Deactivation and Decommissioning
Focus Area

Demonstrated at
Mound Site
Miamisburg Environmental Management Project
Miamisburg, Ohio

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports (ITSRs) are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend a technology to prospective users.

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

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

All published ITSRs are available on the OST Web site at www.em.doe.gov/ost under "Publications."

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SECTION 1
SUMMARY

Executive Summary

The innovative technology described in this report and demonstrated at the Miamisburg Environmental Management Project (MEMP), Mound Large-Scale Demonstration and Deployment Project (LSDDP), was the Tritium Cleanup Cart designed and built by Lawrence Livermore National Laboratory (LLNL). The purpose of this demonstration was to determine the viability of using this portable tritium scrubbing (cleaning) system both as an alternative to and in concert with the existing Tritium Emissions Reduction Facility (TERF) for localized tritium effluent reduction and glovebox decontamination. The Tritium Cleanup Cart is a stand-alone enabling technology for scrubbing tritium. In this process, gases containing tritium pass through a catalytic oxidation system that converts the tritium gas to tritiated water. The tritiated water is then captured on removable molecular sieve dryers. If the tritium level in these dryers is maintained below the 1,080-curie (Ci) “type A” limit (Code of Federal Regulations (CFR) 49 Section 173.435), it can be easily transported and disposed of at an appropriate waste site as low-level waste. The Tritium Cleanup Cart was originally designed and built as one component of a three-Tritium Cleanup Cart system at LLNL, termed the Portable Tritium Processing System. The system is controlled using a portable console and is movable from laboratory to laboratory for performing the basic tritium processing operations of:

- Pumping and transfer;
- Gas analysis; and,
- Gas phase tritium scrubbing.

The portable unit designed for use at the Mound site consists of two units. The first unit, the Tritium Cleanup Cart enclosure, contains the effluent pumping, reactor, and collections systems. The second unit, the console, contains the control system.

Because the Tritium Cleanup Cart application at Mound is complementary to the site’s central scrubber facility, a baseline technology for direct comparison was not identified. Rather, the Tritium Cleanup Cart system is considered an enabling technology because it enables operations described in this report that are otherwise not possible currently at Mound. The Tritium Cleanup Cart proved to by very effective for tritium effluent scrubbing, by reducing the tritium contamination level and off-gas rate in a glovebox during the demonstration. Cost analysis performed using data obtained in this demonstration reveal that the Tritium Cleanup Cart has a capital cost of $400,000 and a unit cost (life cycle) of $71,940 per glovebox. The Tritium Cleanup Cart unit can clean a tritium-contaminated glovebox for around $80,000 with a production rate of 23 days per glovebox. Major benefits of the equipment include its portability, ease of assimilation into the work environment, and efficiency in performing the demonstration described.

Introduction

During the MEMP Main Hill Tritium facilities deactivation and decommissioning (D&D), a large number of tritium-contaminated systems; manifolds; bottles; trailer banks; and, other components will require decontamination. This report provides an analysis of the cost and performance of the LLNL’s Tritium Cleanup Cart demonstration, performed as part of the Mound Tritium LSDDP. Tritium handling systems designed to perform decontamination and decommissioning must do so in accordance with project requirements. Personnel exposure to contaminants and the environmental release of contaminants must be as low as reasonably achievable (ALARA). After consideration of a variety of tritium removal scenarios, the Tritium Cleanup Cart was designed and built to conform to these rigorous guidelines. The demonstration showed the unique capabilities of this portable tritium decontamination system to enhance the decontamination performance of the current permanent tritium manifold cleaning system, the TERF.

Technology Summary

The Tritium Cleanup Cart functions as a portable tritium scrubber module that is easily moved from one decontamination task to the next. Figure 1 shows the Tritium Cleanup Cart control console and the enclosure. Tritium Cleanup Cart design features include the following:

- A scrubbing process based on catalytic oxidation of tritium, with the resultant tritiated water (HTO) collected on molecular sieve dryers.
- A process flow rate of 45 liters/minute.
- Reactor/dryer efficiency monitored by process flow Femto-Tech tritium monitors in the process piping.
- Molecular (mole) sieve dryer beds configured in series with hygrometers to monitor for moisture breakthrough.
- Pre-heater/reactor redundant temperature/over-temperature controllers to prevent thermal excursions.
- System gas flow via a Senior Flexonics MB601 pump.
- Process flow control via Brooks flow controllers in the main plumbing loop and air inlet system.
- Process thermocouples that provide process stream and enclosure over-temperature control.
- Dryer beds configured for easy removal and disposal.
- Primary process enclosure that can function as a ventilated hood during normal operating conditions but that can be isolated when tritium concentrations inside the enclosure exceed the pre-selected control set point.

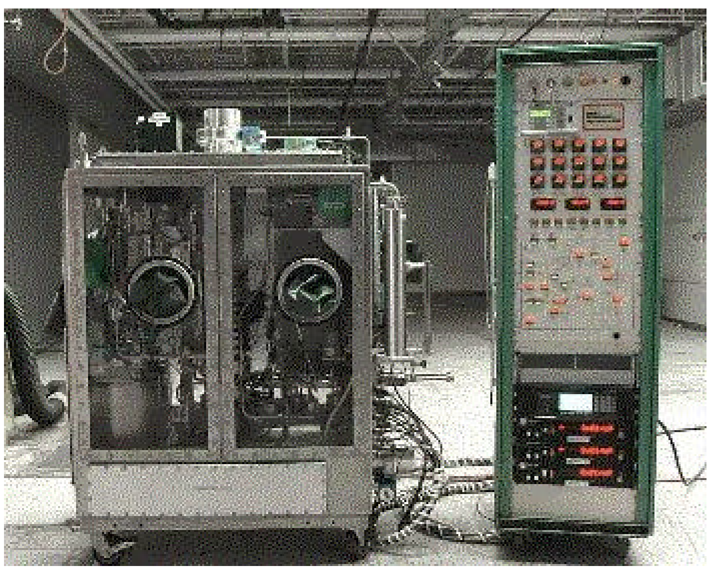

Figure 1. Lawrence Livermore National Laboratory Tritium Cleanup Cart.

Demonstration Summary

The demonstration consisted of using the Tritium Cleanup Cart to decontaminate a tritium-contaminated glovebox. This demonstration was conducted from November 15, 1999 through December 8, 1999; and, consisted of two phases. During Phase I, the glovebox atmosphere was cleaned to remove any free tritium until the lowest level attainable was achieved. During Phase II, moisture was added to the glovebox interior to catalyze the release of tritium that remained deposited on the glovebox walls; equipment; tools; and, other surfaces. This method of decontamination depends on isotopic exchange and is well known in the tritium industry. Data was collected during both phases to analyze the performance, features, and cost of the Tritium Cleanup Cart technology.

LLNL and BWXT of Ohio (BWXTO) personnel performed the demonstration, which lasted 23 days, with tritium scrubbing occurring during 9 days. Data was collected on an average of every 15 minutes while the Tritium Cleanup Cart was in operation.

The data set consisted of measurements of the following parameters:

- Tritium levels at the start and end of operation
- Technical and process difficulties and worker perception and feedback
- Number of hours operated
- Personal protective equipment usage
- Setup, connection, start-up and shutdown analysis, and turnaround times
- Man-hours (setup, relocation, and takedown)
- Environmental conditions (i.e., temperature, pressure, flow, etc.)
- Consumable materials and waste generated
- Oxygen levels in glovebox
- Hygrometer levels in mole sieves

Data was recorded relative to the costs of setup, operation, and personnel and the actual scrubbing time required to clean the glovebox to the point where no additional "releasable" tritium could be removed.

Key Results

Key results of the demonstration include:

- Seventy-four percent (74%) reduction of tritium activity in the glovebox over the 9-day operational test period.

- Tritium-contaminated gloveboxes have a cleanup cost of approximately $80,000/glovebox with a unit production rate of 23 days/glovebox.

Other significant features demonstrated by the Tritium Cleanup Cart include the following:

- Due to its proximity to the demonstration glovebox and dedicated flow capacity, the scrubbing effects of the Tritium Cleanup Cart were immediately observed. This feature permits the portable cleaning system to provide additional support and/or relief for other, less flexible or more fully utilized scrubbing systems or to provide support where no scrubbing capability exists.

- Due to its portability, the tritium scrubber can be maneuvered through doorways and into tight spaces in radiological management areas, connected to various tritium-containing structures (waste drums; gloveboxes; hoods; miscellaneous shipping containers; etc.), and used with a minimum of logistical support to scrub in almost any tritium-contaminated atmosphere.

- Since the reactor unit within the Tritium Cleanup Cart can be easily and inexpensively replaced, the Tritium Cleanup Cart can also be used in situations where the tritium effluent contains catalytic poisons that may be detrimental to expensive in-house systems. The effects of the scrubbing operation can be monitored in real time using the Tritium Cleanup Cart, as can the effects of spraying or flooding the enclosure with moist air. When incorporated within an effective overall deactivation and decommissioning strategy, the fabrication costs of the Tritium Cleanup Cart may be fully recovered by improvements in efficiency resulting from its use.

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Licensing

No licensing activities were required to support this demonstration.

Permitting

Radiological work permits were required for operation of the Cleanup Tritium Cleanup Cart, for connecting the lines to the glovebox, and for entering and working in a radiological management area.

Website

The Mound Tritium LSDDP website is http://www.doe-md.gov/LSDD/lsdd_main_page.htm.

Other

All published ITSRs are available on the OST website at www.em.doe.gov/ost under "Publications." The Technology Management System, also available through the OST website, provides information about OST programs, technologies, and problems. The OST reference number for the Tritium Cleanup Cart is 2974.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goal and Objectives

The goal of this demonstration was to determine whether the performance of the centralized tritium cleaning system, at the Mound tritium facilities, could be significantly augmented by using the portable Tritium Cleanup Cart. The demonstration objectives were to collect operational and cost data to verify that:

- The system reduced glovebox tritium levels to that acceptable for transporting the glovebox to another DOE facility.
- The system met all Mound facility access requirements.

Technology Description

The Tritium Cleanup Cart demonstration at Mound was purposely designed to emulate common deactivation and decommissioning scenarios. As such, the Tritium Cleanup Cart was successfully used (in conjunction with the glovebox, tritium monitor) to interrogate glovebox tritium levels and to determine when effluent scrubbing was leveling off. When leveling-off occurred, a "saturation" technique was employed to liberate more tritium. This technique consisted of spraying down the glovebox interior with ammoniated window cleaner. This operation initially spiked the tritium levels inside the glovebox, whereupon the Tritium Cleanup Cart was used to scrub the free tritium until the levels stabilized again. The process was done numerous times until the spraying had minimal impact on the tritium levels inside the box, indicating that most of the readily released tritium was removed via the scrubbing process. Shortly before the Tritium Cleanup Cart demonstration was deemed complete, warm moist air was introduced into the glovebox environment, again in an attempt to free as much of the surface-bound tritium as possible. This action liberated minimal additional tritium, and the glovebox was deemed ready for ventilating shortly thereafter. At this point in the process, most deactivation and decommissioning projects would open the glovebox to the facility stack, and the glovebox disposition preparation operation would be deemed complete.

The entire operation from the time the Tritium Cleanup Cart was moved into Building SW, room 147—including Tritium Cleanup Cart hookup, check-out, purging, spraying, and final scrubbing—took 23 work days, nine of which were actual test days.

System Operation

Normal system operation includes circulating tritium-contaminated gas steams, removing the tritium as tritiated water, and storing the water on dryer beds. The dryer beds are removed for waste disposal when they are full. A prototypical tritium decontamination operation requires the use of the three modules shown in Figure 2. This portable tritium processing system, designed at LLNL, is made up of modular units that include:

- A pump transfer cart, which provides the interface between the system and the manifolds or vessels to be decontaminated.
- A gas analysis cart, which houses a commercial quadruple residual gas analyzer and pumping station that identifies tritium and determines if a combustible gas mixture (e.g., 4 percent or greater hydrogen in air) is present.

- A scrubber or cleanup cart, controlled by the central control console, uses the information relayed from the analyzer to the console, the operator routes the gas to the correct location within the processing system. The decision is based not only on tritium content but on other variables as well, such as the presence of combustible gas mixtures or materials that would degrade the performance of the scrubber module. Depending on its tritium content, the diluted gas is either pumped to a shipping vessel in the pump transfer module for later tritium recovery or sent to the scrubber module for tritium removal.

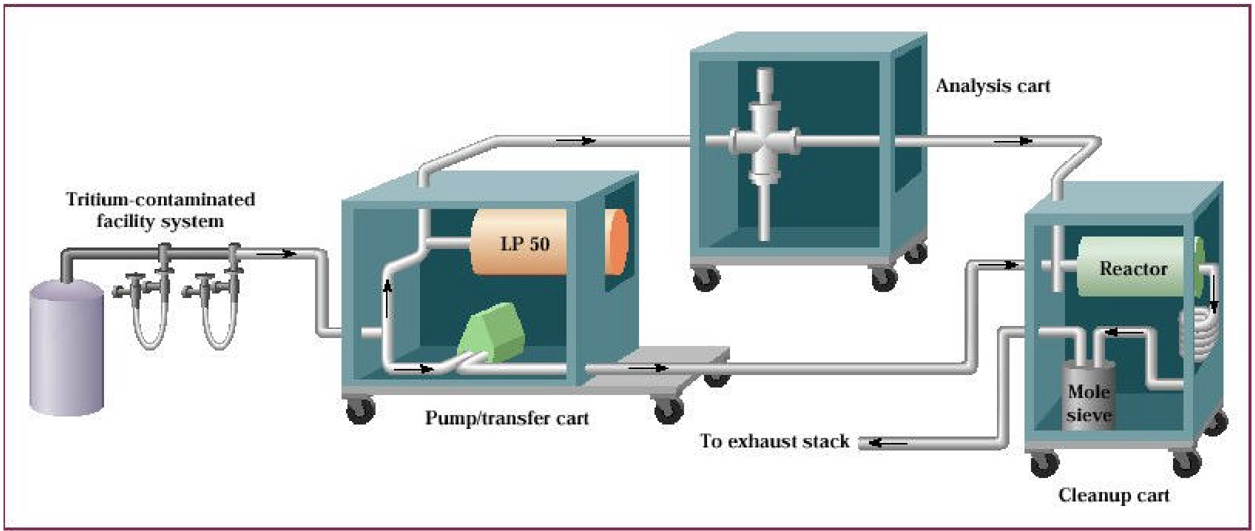


Figure 2. Schematic of the portable tritium processing system.

The scrubber removes the tritium from the circulating gas in several steps. First, the gas is catalytically oxidized. Any molecular hydrogen species, such as H_2 or HT, reacts with heated copper oxide (schematically shown in the "Reactor" in Figure 2. and pictured in Figure 3.) to form water vapor (e.g., H_2O or HTO). The water vapor, including tritium, is collected on molecular sieve dryer beds containing minerals with sponge-like structures. Two molecular sieve dryer beds are attached in series, each with its own downstream moisture monitor. When the monitor for the first bed indicates that the bed has become saturated, the operator stops the process and removes the saturated bed for disposal as low-level waste (less than 1,080 Ci of tritium). The second bed catches any vapor that passed through the first bed if the process was not stopped in time. The second bed replaces the first bed, and in turn, a new fresh bed replaces the second bed.

Once the box tritium level has been lowered as much as possible, the glovebox can be further decontaminated by filling it with room air and then flushing the air through the scrubber module until the tritium contamination is low enough to allow for safe disassembly. During flushing, the inlet and outlet tritium monitors reveal the progress of decontamination.

Figure 3. Scrubber module catalytic reactor.

For cleaning large enclosures, such as gloveboxes, the scrubber module can also function on its own. In addition, in the event of tritium leakage into the pump transfer or gas analysis module secondary enclosures, the scrubber module evacuates and scrubs those gases. In the event that the scrubber module itself fails, a duplicate scrubber module can be used to clean up the failed scrubber. Once the failed scrubber is operating correctly again, normal processing can resume.

Table 1 summarizes the operational parameters and conditions of the Tritium Cleanup Cart.

Table 1. Operational parameters and conditions of the Tritium Cleanup Cart demonstration

Working Conditions	
Work area location	Mound site, Miamisburg, Ohio; Building SW, room 147
Work area access	Miamisburg Environmental Management Project.
Work area description	The Main Hill tritium area of Mound includes areas of Buildings R, SW, and T, which contained laboratory and process areas that handled tritium. Some of the process equipment was exposed to relatively pure tritium and is highly contaminated. This equipment is housed in a secondary containment consisting of gloveboxes and fume hoods. These gloveboxes and fume hoods are installed in individual rooms within the building.
Work area hazards	High-levels of tritium contamination in some areas
Equipment configuration	The portable glovebox enclosure is mounted on wheels with seismic brackets for mounting to the floor if required. The enclosure is stainless steel with Lexan windows. All internal piping that contacts tritium-contaminated gas streams is constructed from stainless steel tubing and sealed with metal gaskets.
Labor, Support Personnel, Specialized Skills, and Training	
Work crew	• 1 lead test engineer • 1 radiological control technician • 1 Tritium Cleanup Cart operator
Additional support personnel	• 1 SW building radiological point of contact • 1 SW building subject matter expert • 1 SW building safe shutdown supervisor • 1 SW/R building manager • 1 Main Hill tritium waste coordinator
Specialized skills or training	• Personnel operating the Tritium Cleanup Cart require training in accordance with LLNL and BWXTO - Mound requirements. • Data collectors were trained in data collection techniques. • Personnel involved in the demonstration were trained under Radiological Worker II guidelines.
Waste Management	
Primary waste generated	Lab trash (mole sieves, wipes, gaskets, tape, etc.)
Secondary waste generated	Disposable personal protective equipment
Waste containment and disposal	All waste generated by the demonstration was handled and disposed of according to the Mound Waste Management Plan.
Equipment Specifications and Operational Parameters	
Technology design purpose	Efficient tritium scrubbing and cleanup in the field
Tritium Cleanup Cart specifications	Weight: 1,000 pounds Dimensions (inches): Height=63; Length=60; and, Depth=40 Maximum working pressure: 21 psia Maximum allowable working pressure: 40 psia
Portability	Portable; it can be taken from one laboratory to another.
Materials Used	
Work area preparation	Staging of the demonstration area consisted of proper setup methods for working with any tritium contamination area (i.e., step-off pads, radiological waste receptacles, adequate supply of proper personal protective equipment, decontamination supplies).

Table 1. Operational parameters and conditions of the Tritium Cleanup Cart demonstration (Continued)

Materials	• Portable tritium monitor • Hand tools for Tritium Cleanup Cart installation; disassembly; and, removal • Fittings: compression of ¼-inch and ½-inch size to seal the disconnected lines • 30-ampere power cable • Portable transformer (verify three-phase power requirement) • Compressed air supply (to operate valves)
Personal protective equipment	During the course of the demonstration, all personnel collecting or manipulating samples were required to wear the appropriate personal protective equipment to perform work, as specified by the radiological work permits for radiological protection, as well as safety glasses, safety shoes, and leather gloves.

Note:
BWXTO = Babcock and Wilcox of Ohio

Safety-Related Design Features

Safety-related design features were included to prevent or mitigate the consequences of a potential accident. These features included a secondary confinement and tritium monitors.

Secondary confinement was addressed by having all process plumbing contained inside a portable glovebox enclosure. The enclosures function as air atmosphere gloveboxes but can be converted to inert atmosphere boxes if required. Both enclosures are provided with passive glovebox bubbler overpressure protection that vents overpressure to an appropriate source (e.g., TERF, stack, etc.) and tritium monitors. In the case of under-pressure, the secondary enclosure pulls makeup air into the enclosure through the negative-side bubbler.

Tritium monitors are located in the Tritium Cleanup Cart primary and secondary enclosures and in the residual gas analysis Tritium Cleanup Cart secondary enclosure. If a primary system component leaks, the secondary enclosure tritium monitor shuts down the Tritium Cleanup Cart's heaters and closes all air-operated valves on both Tritium Cleanup Carts. The cooling secondary enclosure air inlet; the outlet shutoff; and, various gas handling system sections are isolated when the necessary valves automatically close, thus containing the leak inside the secondary enclosure. If the process discharge tritium monitor detects unacceptable levels of tritium in the Tritium Cleanup Cart exhaust air, the air-operated inlet and outlet valves close automatically and place the Tritium Cleanup Cart in the internal recycle mode.

SECTION 3
PERFORMANCE

Problems Addressed

The SW/R building complex Safe shutdown requires purging and flushing of tritium-contaminated gloveboxes. Purged gases are typically processed through the TERF. The proposed technology involves using a portable system that employs technology similar to the TERF to convert tritium into its oxide form and then capture the moisture on a dryer bed. The demonstration goal was to prove that deploying the Tritium Cleanup Cart as a complement to the fixed central cleanup system was possible and valuable.

Demonstration Plan

This technology demonstration focused on scrubbing a tritium-contaminated glovebox at the MEMP Mound site, Building SW, room 147. The selected glovebox was connected to the TERF. During this demonstration, the TERF connections and valves were left in the "trickle purge" configuration, which allowed for a nominal 6-cubic feet per hour flow rate of nitrogen into and out of the glovebox. However, the Tritium Cleanup Cart needed oxygen to efficiently remove the tritium. In this configuration, the glovebox out flow is directed to the TERF system. The demonstration lasted 23 days, including 9 days of run time. The demonstration was divided in two phases. Phase I started with the Tritium Cleanup Cart connection to the glovebox; testing of all Tritium Cleanup Cart components; and, scrubbing the glovebox to process the free tritium. Phase ll involved scrubbing the glovebox, while spraying its internal walls and the inside components to try to release the attached tritium. The Tritium Cleanup Cart was off gassing at night. As a result, overnight tritium levels would rise and then, after cleaning, be brought to even lower limits the following day. On the last day, the glovebox was scrubbed without spraying to return the box to a steady-state configuration. While the Tritium Cleanup Cart was scrubbing, data was recorded every 15 minutes for a total of 56-operating hours.

Demonstration Site Description

The Mound site Main Hill tritium area includes areas of buildings R, SW, and T. These buildings contain laboratory and process areas that handled tritium. Some process equipment was exposed to relatively pure tritium and is highly contaminated. This equipment is housed in secondary containment consisting of gloveboxes and fume hoods. These gloveboxes and fume hoods are installed in individual rooms within the buildings. There are high levels of tritium in process piping; equipment; and, tanks. Lower levels exist in gloveboxes, buildings, and contaminated soil and groundwater around the buildings. The location selected for the LLNL Portable Tritium Cleanup Cart initial demonstration was Building SW, room 147. This room contained abandoned gloveboxes with limited tritium levels.

Results

Tritium Cleanup Cart portability was amply demonstrated. It was rolled into SW Building, room 147, with ease since both the enclosure and the electronics rack are small enough to fit through standard-size 36-inch doors. After connecting the Tritium Cleanup Cart to the glovebox and fume hood (used for Tritium Cleanup Cart exhaust) during the Phase I, the Tritium Cleanup Cart was connected to its power and air supplies and was ready for leak and function testing.

This demonstration was designed to simulate common D&D scenarios. During Phase II, the Tritium Cleanup Cart and the existing glovebox tritium monitor measured glovebox tritium levels and determined when the effluent scrubbing effectiveness was leveling off. When this leveling-off occurred, a "saturation" technique was employed during Phase II to liberate more tritium from the glovebox interior. This technique consisted of spraying down the glovebox interior with ammoniated window cleaner. This operation initially increased the tritium levels inside the glovebox, whereupon the Tritium Cleanup Cart was again used to scrub the free tritium until the levels stabilized. This process was repeated until the spraying had minimal impact on the tritium levels inside the glovebox. This indicated that most of the readily released tritium was removed. After the spraying phase, warm moist air was introduced into the glovebox environment, in another attempt to free as much of the surface-bound tritium as possible.

This procedure liberated minimal additional tritium, and the glovebox was deemed ready for venting. Typical D&D projects would open the glovebox to the facility stack at this point, and the glovebox would be considered ready for disposal.

At the Mound site, most gloveboxes are connected to the TERF. The glovebox used in the demonstration was connected to the TERF for many years. The tritium level at the demonstration beginning was 663 $\mu Ci/m^3$ with a fresh nitrogen purge. At the demonstration end, after subtracting the background count, the level was 175 $\mu Ci/m^3$. Due to the many spray and scrub cycles, considerably more tritium was removed than is indicated. A typical day's cleanup operation is shown in Figures 4 and 5. These figures were prepared from data recorded in data logs similar to the ones shown in Tables B.1 and B.2 (Appendix B). Figure 6 gives an overview of all 9 days of operation. During spraying efforts inside the glovebox, the levels became as high as 4,649 $\mu Ci/m^3$ (Figure 4) and 5,165 $\mu Ci/m^3$ (day 3). Tritium levels on the last day (Figure 5) leveled off at 1,650 $\mu Ci/m^3$. These results show that substantial additional decontamination by the Tritium Cleanup Cart was possible despite years of continuous glovebox connection to the TERF.

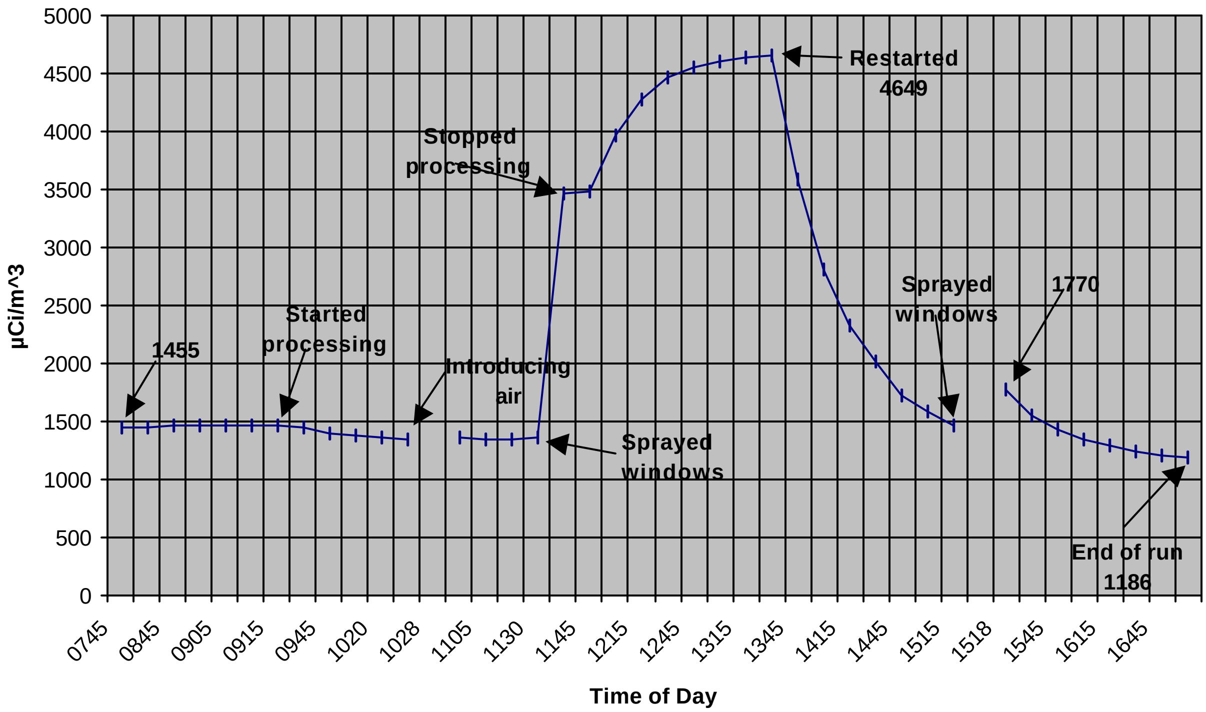


Figure 4. Tritium Cleanup Cart operation on day 2 (11/17/99).

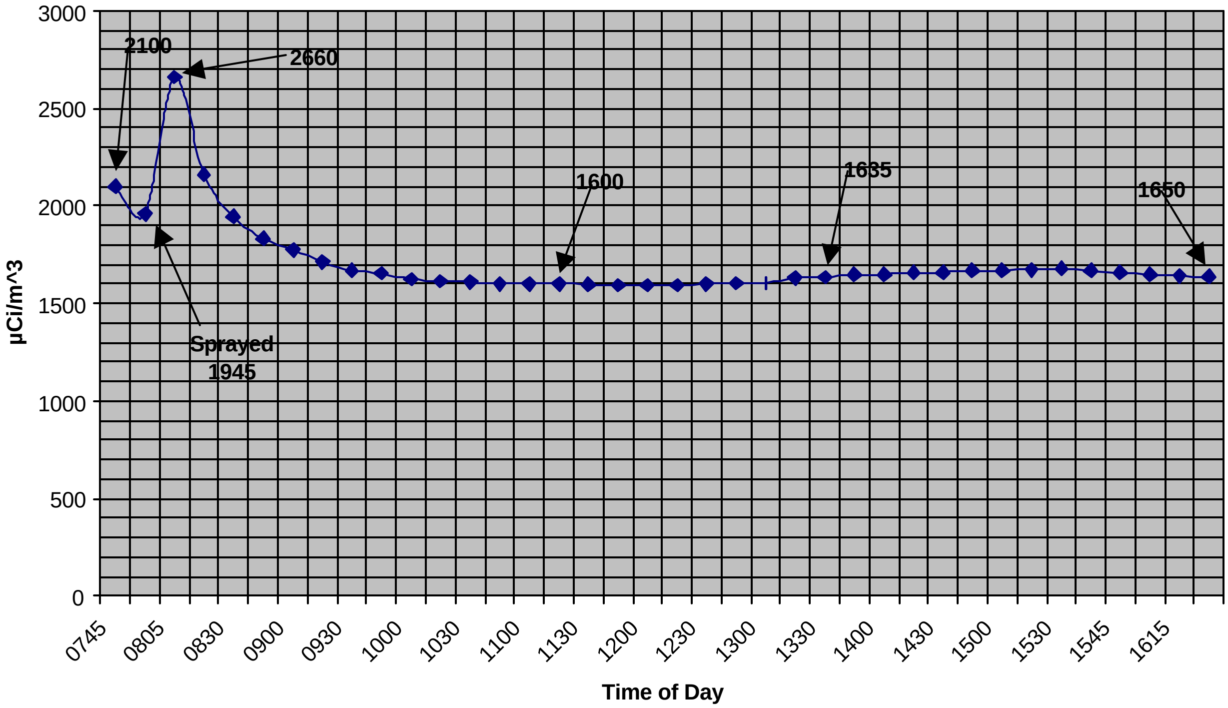


Figure 5. Tritium Cleanup Cart operation on the last day (12/8/99).

Contaminant Removal

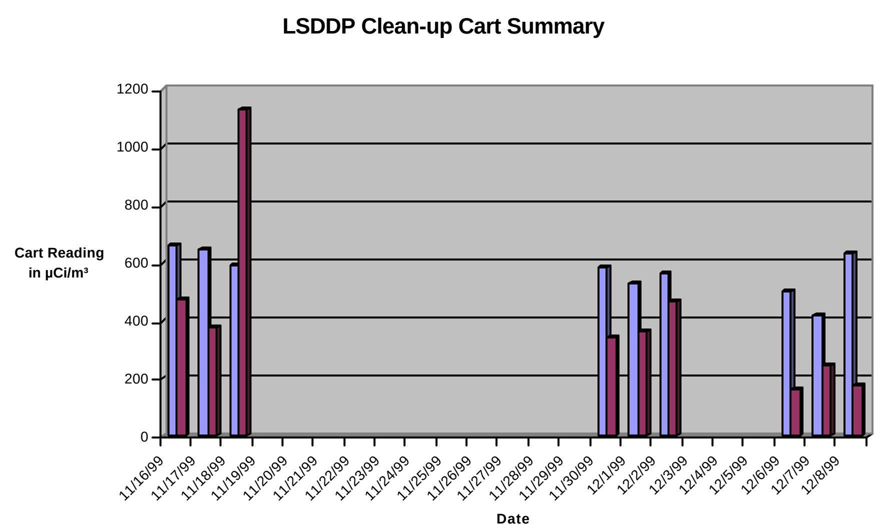
The total amount of tritium removed from the glovebox can be derived as the sum of all negative slope lines shown on the "LSDDP Tritium Cleanup Cart Graphs" for each day's activity. These graphs are contained in the "Operator's Debriefing" Appendix of the *Detailed Technical Report* (Lopez 2000) and were generated from the data presented in Table B.1 (Appendix B). Table B.3 (Appendix B) summarizes these totals in the column titled "Sum of Negative Slope Operations." The average flow rate through the Tritium Cleanup Cart was defined as 45 liters per minute. This rate can be used to calculate the total volume of flow through the Tritium Cleanup Cart for the test as follows:

45 liters per minute = 2.7 m^3 per hour X 56 hours for test = 151.2 m^3 of flow

Thus, the total tritium removed over the operational test is the total tritium removed from glovebox (total of column 3 in Table B.3) multiplied by the volume.

9,364 ìCi per m^3 x 151.2 m^3 = 1,415,836.8 ìCi = 1.42 Ci

Figure 6 shows a comparison of the Tritium Cleanup Cart start of day and end of day readings over the 9 days of the test.



	11/16/99	11/17/99	11/18/99	11/30/99	12/1/99	12/2/99	12/6/99	12/7/99	12/8/99
Series1	663	645	590	584	528	565	500	420	635
Series2	471	376	1133	340	362	470	165	248	175

Figure 6. Tritium Cleanup Cart data summary (9 days).

The Tritium Cleanup Cart demonstration results lead to several important conclusions:

- Using a portable tritium scrubbing capability as an alternative to and in addition to TERF for localized tritium effluent scrubbing is viable. This demonstration showed that a sophisticated piece of equipment, designed and built outside the MEMP site, could be brought onto the Mound site; connected to an existing contaminated glovebox; and operate. This equipment was successfully used to independently clean a glovebox without interfering with the TERF or disrupting otherwise normal operations. Additionally, it may be more convenient to use the portable cleanup system because of the presence of various catalyst “poisons” that might be harmful to the TERF.

- The Tritium Cleanup Cart proved to be an effective, rapid decontamination tool for tritium-contaminated gloveboxes. In this particular case, the goal was to reduce the glovebox levels as far as possible and as quickly as possible. This was done in accordance with ALARA principles. In most “real world” D&D applications, thorough, scrubbing with the Tritium Cleanup Cart would be followed up by ventilating the glovebox with its remaining minimal tritium inventory to the facility stack in prepartion for final dismantlement or other disposal. This approach better supports ALARA objectives because it minimizes release to the environment while maximizing the primary objective of worker protection through eliminating the "tritium rebound" effect that is incurred by terminating cleanup operations, then resealing the glovebox (as was done at the conclusion of the Tritium Cleanup Cart demonstration). Once the glovebox is opened to the stack, contamination levels will continue to decline until the glovebox structure is (in most cases) disassembled and disposed of in accordance with governing policies.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline Technology Description

Because the Tritium Cleanup Cart application at the Mound site is complementary to the site's central scrubber facility (TERF), a baseline technology for direct comparison is not identifiable. Rather, the portable Tritium Cleanup Cart system is properly considered an enabling technology since it makes possible the uses described in this report.

This technology is intended for use in a facility where access exists to an operational tritium vent system such as the TERF or facility ventilation stack systems that are typical of buildings such as SW and R at the Mound site.

Technology Applicability

The Tritium Cleanup Cart can be used to supplement the TERF or can be used in areas where TERF connections to gloveboxes and other equipment do not exist. Other applications are in gloveboxes where chemicals are present that may poison the TERF catalyst, since the reactors on the Tritium Cleanup Cart are consumable items. This technology addresses DOE's needs for effective transportable tritium gas handling and glovebox cleanup capability.

This technology can be used at any DOE site that can benefit from a stand-alone, portable tritium scrubbing capability. The system has proven successful, and construction of duplicate units is underway.

Patents, Commercialization, and Sponsorship

No issues related to patents, commercialization, or sponsorship are pending.

SECTION 5
COST ANALYSIS

Introduction

The objective of this cost analysis is to provide decision makers tasked with deactivation and decommissioning programs with sound cost information on new and innovative technologies that may provide economic advantages over standard methodologies for use in the operations task mode. This analysis strives to develop realistic estimates representative of actual tasks to be performed in the deactivation and decommissioning arena within the DOE complex or other agencies with similar needs.

Methodology

The Mound facility lead test engineer (LTE) collected cost information. Test data were collected on a quarter-hour basis for the test duration. The LTE and the Tritium Cleanup Cart operator were familiar with the equipment and required no training. The Tritium Cleanup Cart operator should be specialized in its use. Tritium Cleanup Cart operation is quite complex, and as such, it is cost effective to have trained operators furnished by the manufacturer. For this demonstration, the team was temporarily located at Mound for the test duration. The LTE was responsible for the test data collection and what is considered a test-specific cost item.

The cost analysis for this activity consists of a determination of a viable unit price for the Tritium Cleanup Cart cost to clean a tritium-contaminated glovebox. Data supporting the unit price analysis were taken directly from the LTE's quarter-hour data compilations. All calculations and supporting information for the unit price analysis are included in Appendix C of this report. A cost estimate for the unit price determination was prepared using the U.S. Army Corps of Engineers Micro-Computer–Assisted Cost Engineering System "Checkrate" program.

The basic assumptions for this analysis are as follows:

- The Tritium Cleanup Cart economic life is defined by the Mound "Main Hill Tritium" Decommissioning Project duration. Currently the project schedule end is 2007. The economic unit cost for the Tritium Cleanup Cart is calculated on this 7-year life.

- The expected Tritium Cleanup Cart equipment life is about 25 years. Appendix C contains supporting calculations for the equipment unit cost for the Tritium Cleanup Cart based on 25-year operational life.

- The labor to operate the Tritium Cleanup Cart will always be supplied from the manufacturer.

- Support services will be supplied from local resources.

Cost Analysis

In this demonstration, the Tritium Cleanup Cart operation lowered the tritium contamination levels in the glovebox to a point where further off gassing would be below a rate of 10×10^{-6} Ci per day. At this level the glovebox was cleaned and could be opened to the atmosphere. Key results of the cost analysis include:

- Unit production rate of 23 days per glovebox.
- Economic equipment life of 22,217 operating hours/equipment life.
- Total economic operating life of 216 operating hours/economic life.
- Total labor unit cost of $71,940.00 per glovebox (see Table C.2, Appendix C).

Table 2 contains a summary of the various components of the total cost.

Table 2. Cost data for the Tritium Cleanup Cart

Capital cost of Tritium Cleanup Cart	$400,000.00	
Labor unit operation hour cost	$1284.64	
Life of equipment	7 years	25 years
Equipment rate (dollars per hour) includes all associated costs	$128.53	$48.20
Supplies cost	$18.00	
Swipe analysis cost	$109.20	
Labor cost per equipment operating hour	$1284.64	
Personal protective equipment cost	$48.40	

Supporting documentation for the values given in Table 2 are given in Appendix C of this report.

The equipment rates include the base rate developed using the "Checkrate" program and correction factors for the tritium trap scheduled maintenance, replacement, and disposal and the Tritium Cleanup Cart disposal at the end of the operational life. Details of this cost development are given in Appendix C under "Equipment Cost Calculations."

Summing the various cost elements above on the same unit basis yields the following unit price totals.
For the equipment operation life (25 years),

$71,940.00 labor + $48.20 equipment/hour (56 hours) = $74,814.88/cleanup

For the equipment economic life (7 years),

$71,940.00 labor + $128.53 equipment/hour (56 hours) = $79,313.36/cleanup

The total cost of the D&D operation of the glovebox in Building SW, room 147, accounting for equipment and personnel, was $77,225.60. When the cost of the approval process is coupled with the above costs, the total is $157,885.60, as shown in Table 3, below. See Table C.1 (Appendix C) for a total cost breakdown.

Table 3. Cost analysis for the Tritium Cleanup Cart demonstration

Cost for approval process	$ 80,660.00
Setup of equipment	$ 2,809.00
Operation of the Tritium Cleanup Cart	$ 41,650.00
Equipment disassembly	$ 13,560.00
Consumables	$ 66.40
Detailed technical report, LTE le	$ 19,140.00
Total cost of demonstration	$157,885.60

Cost Conclusions

The major cost for the Tritium Cleanup Cart demonstration was the operation labor. From the above summary of the unit prices, the labor impact accounts for more than 85 percent of the total cost. The equipment purchase cost, although significant, is mitigated by its relatively long life.

This cost analysis estimates that the Tritium Cleanup Cart can clean a tritium-contaminated glovebox for around $80,000. This in-situ cleaning of gloveboxes will facilitate follow-on segmenting without additional decontamination. The normal method of disposing of gloveboxes is to cut the boxes into manageable pieces within a containment structure and to decontaminate the box segments before disposal as low-level waste. Thus, decontaminating the gloveboxes before segmentation can result in substantial cost savings.

For full deployment, there would be an additional cost for the training of Tritium Cleanup Cart operators.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

No special regulatory considerations were required to demonstrate or implement this technology. However, prior to the demonstration initiation, separate radiological work permits (RWPs) were required for the Tritium Cleanup Cart operation; for connecting the lines to the glovebox; and, for entering or working in a radiological management area. Vials containing the swipes and the scintillation cocktail were disposed of in proper waste stream containers provided by the Mound site’s Waste Management. Also, all personal protective equipment (PPE) was disposed of in the proper waste receptacles.

Safety, Risks, Benefits, and Community Reaction

During the course of the demonstration, per the RWPs, all personnel working in the glovebox were required to wear the appropriate PPE to perform the work. When operating the Tritium Cleanup Cart, no PPE was required.

Thorough evaluation of this technology has not revealed any community safety issues or adverse environmental impact. Indeed, effective deployment will increase worker safety and decrease environmental impact of D&D operations by reducing contamination and decreasing emissions. It is anticipated that the data from this demonstration would be sufficient to solicit regulatory acceptance of the demonstrated technology.

SECTION 7
LESSONS LEARNED

Implementation Considerations

Since MEMP gloveboxes have a nitrogen purge and the LLNL Tritium Cleanup Cart requires oxygen to react with and collect tritium as tritiated water, the Tritium Cleanup Cart operator had to ensure an adequate oxygen level in the glovebox by injecting air. The end goal was to achieve a level of 2 percent oxygen within the glovebox. The process was time consuming for the following reasons:

- The Tritium Cleanup Cart takes clean air from within its own enclosure injecting the air into the glovebox. The volume of air is the same as the volume of the entire Tritium Cleanup Cart processing system. While watching the oxygen level closely, the operator observed the level rising very slowly. When the oxygen level reached 1.5 percent, the rate accelerated and the level increased quickly even though the operator was not injecting any more air into the glovebox system. The oxygen level subsequently exceeded the nominal end point of 2 percent, reaching a final level of 2.9 percent in the glovebox.

- Although, not a hazard, the operators learned that waiting 3 to 4 minutes between each oxygen injection was beneficial. It allowed any mixing and/or gas dynamics to take effect, thereby allowing for a slower, more controlled oxygen increase into the glovebox system.

Technology Limitations and Needs for Future Development

The Mound site has mainly 220-vac in the chosen demonstration location and the Tritium Cleanup Cart requires a 208-volt, 30-ampere, 3-phase power source. To supply this, a portable transformer was brought in and electrically wired to the Tritium Cleanup Cart. This transformer was located on the Mound site and was supplied for the demonstration free of charge. The only additional cost was to have an electrician wire the transformer. If the Tritium Cleanup Cart is going to be used at another site, a transformer may have to be purchased.

APPENDIX A
REFERENCES

Lopez, A. March 2000. *Detailed Technology Report for the Lawrence Livermore National Laboratory Portable Tritium Cleanup Cart.* Morgantown, W. Va.: U.S. Department of Energy, National Energy Technology Laboratory.

U.S. Army Corps of Engineers. Louisville District. January 2000. *Tritium Cleanup Cart Cost Analysis.*

APPENDIX B
DEMONSTRATION DATA

Table B.1 - Sample LSDDP Tritium Cleanup Cart daily log: day 2

		Start T2 Levels				End T2 Levels			
Date	Start Time	Glovebox Monitor (µCi/m³)	Tritium Cleanup Cart Monitor Nr. 1 (µCi/m³)	Tritium Cleanup Cart Monitor Nr. 2 (µCi/m³)	Tritium Cleanup Cart Monitor Nr. 3 (µCi/m³)	Room Monitor (µCi/m³)	Glovebox Oxygen Level (%)	Hygro - meter (%)	Comments
11/17/99	07:45	1455							
	08:35	1455				3	0.2		Not processing
	08:45	1472				4	0.2		Open air inlet - increase oxygen
	09:00	1470				4	0.3		Heaters still warming up
	09:05	1465				4	0.3		
	09:10	1470				4	0.3	0.021	
	09:15	1470	0	0	4	3	0.3	0.021	Started processing
	09:30	1442	0	0	3	4	0.6	0.023	
	09:45	1400	1	3	4	5	0.6	0.025	
	10:00	1380	4	0	3	4	0.6	0.029	
	10:20	1357	2	2	6	4	0.5	0.032	Stopped oxygen
	10:27	1353	4	1	3	3	0.5	0.032	Stopped processing
	10:28						0.5		Introduced oxygen to glovebox
	10:55	1360				5	1.3		
	11:05	1353					2.0	0.3	
	11:15	1344	2	6	4	5	1.8	0.03	Started processing
	11:30	1361				4	1.6		Sprayed windows
	11:40	3460				3	1.6		Stopped processing
	11:45	3480				6	1.6	0.03	
	12:00	3970				4	1.6	0.03	
	12:15	4270				3	1.6	0.03	
	12:30	4460				3	1.5	0.03	
	12:45	4552				3	1.5	0.03	
	13:00	4605				4	1.4	0.03	
	13:15	4646				4	1.4	0.03	
	13:30	4649				3	1.4	0.03	
	13:45	3585	3	4	1	4	1.3	0.032	Start processing
	14:00	2805	6	1	-3	5	1.3	0.03	
	14:15	2325	4	3	-2	3	1.2	0.03	
	14:30	2010	4	2	-4	3	1.2	0.03	
	14:45	1730	4	3	-3	3	1.2	0.034	
	15:00	1582	4	2	-2	3	1.1	0.032	
	15:15	1470	4	2	-2	3	1.1	0.034	
	15:16								Sprayed windows
	15:18	1770							
	15:30	1550	4	4	-1	4	1.1	0.034	
	15:45	1425	2	3	-2	3	1.0	0.034	
	16:00	1344	3	3	0	3	1.0	0.034	
	16:15	1285	4	1	0	3	1.0	0.034	
	16:30	1240	3	1	0	4	1.0	0.034	
	16:45	1207	3	3	-1	3	0.9	0.034	
	17:00	1186	2	2	-2	3	0.9	0.034	End of run

Table B.2 - Sample LSDDP Tritium Cleanup Cart daily log: day 9 [end]

		Start T2 Levels				End T2 Levels			
Date	Start Time	Glovebox Monitor (μCi/m^3)	Tritium Cleanup Cart Monitor Nr. 1 (μCi/m^3)	Tritium Cleanup Cart Monitor Nr. 2 (μCi/m^3)	Tritium Cleanup Cart Monitor Nr. 3 (μCi/m^3)	Room Monitor (μCi/m^3)	Glovebox Oxygen Level (%)	Hygro-meter (%)	Comments
12/08/99	07:45	2100	1	3	0	4	3.3	0.015	Start processing increase oxygen
	08:00	1960	1	3	0	3	3.8	0.017	Sprayed box
	08:05	2660							
	08:15	2160	2	3	0	4	5.7	0.019	
	08:30	1945	1	1	0	3	7.8	0.023	
	08:45	1833	4	5	0	4	9.8	0.027	
	09:00	1775	5	4	4	6	10.9	0.029	
	09:15	1712	6	3	2	3	12.0	0.034	
	09:30	1670	4	7	3	4	12.9	0.036	
	09:45	1656	6	3	2	3	13.7	0.038	
	10:00	1626	6	5	1	3	14.4	0.042	
	10:15	1613	7	3	4	4	14.9	0.042	
	10:30	1610	7	3	1	4	15.4	0.048	
	10:45	1600	7	7	0	4	15.7	0.052	
	11:00	1600	8	4	1	4	16.1	0.054	
	11:15	1600	8	5	5	3	16.2	0.061	
	11:30	1598	7	6	1	3	16.4	0.061	
	11:45	1592	8	4	2	4	16.5	0.061	
	12:00	1592	8	3	3	5	16.6	0.630	
	12:15	1592	8	5	2	4	16.8	0.067	
	12:30	1600	8	8	3	4	16.9	0.067	
	12:45	1606	6	5	1	3	16.9	0.069	
	13:00	1606	9	5	1	5	16.9	0.069	
	13:15	1630	8	6	1	3	17.0	0.069	
	13:30	1635	8	8	2	3	17.1	0.069	
	13:45	1650	8	3	1	4	17.1	0.061	
	14:00	1650	7	2	1	4	17.2	0.067	
	14:15	1660	8	2	3	3	17.2	0.069	
	14:30	1660	8	7	2	4	17.2	0.073	
	14:45	1670	8	3	0	5	17.3	0.077	
	15:00	1670	8	4	3	3	17.3	0.077	
	15:15	1675	7	3	1	4	17.3	0.077	Turned off injector
	15:30	1680	8	6	0	4	17.1	0.069	V2 open - no reason – closed V2
	15:30	1670	8	3	1	3	16.8	0.069	
	15:45	1660	8	4	1	4	16.4	0.067	
	16:00	1650	8	4	2	4	16.0	0.067	
	16:15	1642	8	5	0	4	15.5	0.061	
	16:30	1640	8	4	0	3	15.1	0.059	

Table B.3 - Tabulation of operating hours and tritium readings for all negative slope events

Date	Operating Hours of Tritium Cleanup Cart (in hours)	Sum of Negative Slope Operations (ìCi/m^3)
11/16/99	5	257
11/17/99	5	2516
11/18/99	2.5	3265
11/30/99	6.75	239
12/01/99	8.25	1058
12/02/99	2.75	1055
12/06/99	8	340
12/07/99	9	174
12/08/99	8.75	460
Total	56	9364

APPENDIX C
COST CALCULATION SUPPORT DETAILS

The data in Table C.1 was obtained from the *Detailed Technology Report* (Lopez 2000). These data are used for the development of the unit cost for the operation of the Tritium Cleanup Cart.

Table C.1 - Original breakdown from the *Detailed Technology Report*

Cost for Approval Process			
LLNL writing of paperwork	1 man-month		$19,140.00
BWXTO-Mound paperwork (USQ)	120 hours	@ $70/hour	8,400.00
Travel, paperwork approval	8 trips	@ $4,000 each	$32,000.00
Labor, paperwork approval	24 man-days	@ $110.00/hour	$21,120.00
Setup of Equipment			
Laborers (4 people)	2 hour each	@ $70/hour	$560.00
Electricians (2 people)	4 hour each	@ $70/hour	$560.00
RCT (swiping glovebox)	2 hour each	@ $70/hour	$140.00
Swipe analysis cost	60 each	@ $1.82 each	$109.20
Pre-job briefing (1 hr each)	16 hour	@ $90.00	$1,440.00
Tritium Cleanup Cart Operation			
Lead test engineer	9 days	@ $880.00/day	$7,920.00
Tritium Cleanup Cart Operator	9 days	@ $880.00/day	$7,920.00
BWXTO-Mound technician	9 days	@ $560.00/day	$5,040.00
BWXTO Mound photographer	1 hour	@ $70.00/hour	$70.00
BWXTO-Mound RCT	8 hour	@ $70.00/hour	$560.00
Travel for lead test engineer	5 trips	@ $2,000.00/trip	$10,000.00
Travel for Tritium Cleanup Cart operator	5 trips	@ $2,000.00/trip	$10,000.00
BWXTO-Mound demo techs	2 hour	@ $70.00/hour	$140.00
Disassembly of Equipment			
Lead test engineer	3 days	@ $880.00/day	$2,640.00
Tritium Cleanup Cart operator	3 days	@ $880.00/day	$2,640.00
Travel for lead test engineer	2 trips	@ $2,000.00/trip	$4,000.00
Travel for Tritium Cleanup Cart operator	2 trips	@ $2,000.00/trip	$4,000.00
BWXTO-Mound RCT	2 hour	@ $70.00/hour	$140.00
BWXTO-Mound demo techs	2 hour	@ $70.00/hour	$140.00
Consumables			
Gloves	20 pairs	@ $.42 each	$8.40
Tape	1 roll	@ $5.00/each	$5.00
Lab coats	2 each	@$20.00/ea.	$40.00
VCR gaskets	8 each	@ $1.00/ea.	$8.00
Window cleaner	1 each	@ $5.00	$5.00
Detailed Technical Report			
Lead test engineer	1 man-month		$19,140.00
		Total	$157,885.60

Notes:

BWXTO = Babcock and Wilcox of Ohio;
demo techs = demonstration technicians
LLNL=Lawrence Livermore National Laboratory
RCT = radiological control technician; and,
USQ = un-reviewed safety questions.

Operational Calculations

Production Rate

The defined unit of measure for this test is each glovebox. The total time for this test was 23 days. Within this time, one glovebox was decontaminated. It was the LTE's view that glovebox cleanup using the Tritium Cleanup Cart was independent of the contamination beginning level. The unit of measure for this test is time per glovebox decontamination. The total time for this test was 23 days. Thus, the unit production rate is 23 days per glovebox.

Operational Life

See Table B.1 (Appendix B) for a list of the days of operation and the hours per day of operation. Taking 23 days as the standard operating period for cleaning any glovebox, the operating hours per year can be calculated as follows:

(365 days per year/ 23 days per period) X 56 hours operation/period = 888 operation hours/year

The Tritium Cleanup Cart equipment life is 25 years, based on the usable life of most of the components (see Table C.4). Thus, the total operating equipment life is

888 operation hours/year X 25 years = 22,217 operation hours

The economic life of the equipment can be based on the need at the operational facility. In this instance, the need for the Tritium Cleanup Cart will not extend beyond the scheduled Main Hill Tritium project at the Mound site end. This project is currently scheduled to end in 2007. Thus, an economic life of 7 years is assumed, and the total economic operating life is

888-operation hours/year X 7 years = 6,216-operation hours

Labor Cost Calculations

Many of the cost items included in Table C.1 are not included in the labor cost calculations. The cost for the LTE (and his associated travel); the cost of travel for the approval process; the photographer's cost; and, the detailed technology report cost have not been included because these items are test specific. Travel for the Tritium Cleanup Cart operator is included, based on the assumption that specific operating knowledge of the Tritium Cleanup Cart systems is required and that sending a trained operator is as cost effective as providing on-site training. However, the amount of travel has been reduced to two trips total, one for setup and operation and the other for closedown activities. The operator per-diem is included in the unit rate. The total cost of the approval process has been included because experience has shown that each specific work item at Mound seems to require this same effort. The items that make up the labor cost from a reasonable production scenario are shown in Table C.2.

From Table C.2, the total labor cost of the test is $71,940.00 (not including some items denoted as test specific). Using the equipment operating hours as the unit of interest, the unit labor cost for this test is

$71,940.00/ 56 equipment hours = $1,284.64 per equipment hour

Table C.2 – Summary of labor costs for the Tritium Cleanup Cart test

Approval Process			
LLNL writing of paperwork	1 man-month		$19,140.00
BWXTO-Mound paperwork (USQ)	120 hours X $70.00		$8,400.00
Labor for approval of paperwork	24 man-days X $110.00/hour		$21,120.00
		Subtotal	$48,660.00
Hook-up			
Laborers (4 people)	2 hours each	@ $70/hour	$560.00
Electricians (2 people)	4 hours each	@ $70/hour	$560.00
RCT (swiping glovebox)	2 hours each	@ $70/hour	$140.00
Pre-job briefing (1 hour each)	16 hours	@ $90.00	$1,440.00
		Subtotal	$2,700.00
Tritium Cleanup Cart Operation			
Tritium Cleanup Cart operator	9 days	@ $880.00/day	$7,920.00
BWXTO-Mound technician	9 days	@ $560.00/day	$5,040.00
BWXTO-Mound radiological control technician	8 hours	@ $70.00/hour	$560.00
Travel for operating Cart	1 trip	@ $2,000.00/trip	$2,000.00
BWXTO-Mound demonstration technicians	2 hours	@ $70.00/hour	$140.00
		Subtotal	$15,660.00
Disassembly			
Tritium Cleanup Cart operator	3 days	@ $880.00/day	$2,640.00
Travel for operator	1 trips	@ $2000.00/trip	$2,000.00
BWXTO-Mound radiological control technician	2 hours	@ $70.00/hour	$140.00
BWXTO-Mound demonstration technicians	2 hours	@ $70.00/hour	$140.00
		Subtotal	$4,920.00
		Labor grand total	$71,940.00

Notes:

BWXTO = Babcock and Wilcox of Ohio
LLNL=Lawrence Livermore National Laboratory
RCT = radiological control technician
USQ = un-reviewed safety questions

Equipment Cost Calculations

The equipment cost is part of the total cost for this operation. The equipment rate is the sum of the "Checkrate" program–calculated unit rate plus other extraordinary equipment cost items. The U.S. Army Corps of Engineers' "Checkrate" program is based on the EP-1110 Equipment Rate Book. The other extraordinary equipment cost items consist of three added cost items:

- The change-out of the tritium filter (molecular sieve), to be called the *mole sieve change-out cost*
- The planned replacement of the equipment parts with a life shorter than the total operational life of the unit as a whole, to be called the *equipment item replacement cost*
- Disposal of the Tritium Cleanup Cart at the end of usage

The molecular sieve (mole sieve) used to remove the tritium from the glovebox atmosphere has a life expectancy of 1,000 Ci, based on disposal issues. In this test case, the total amount of tritium removed from the glovebox and deposited on the mole sieve was 14.61 Ci. Assuming that this glovebox is average, the useful life expectancy of the mole sieve is

1000-Ci life/15 Ci per average box = 66.7 boxes

Considering that the calendar time for this test was over 2 months and taking this as an average, a single mole sieve will last 66.7 boxes per sieve/ 6 boxes per year = 11.1 years.

Table C.3 - Labor cost summary for mole sieve change-out (hours)

Task	Hours
Write work package and plan	4
Write job-specific radiological work permits	4
Pre-job meeting for all personnel	4
Demonstration technicians to lay down plastic, etc.	2
Maintenance machinist to remove the window	1
Pipe fitters to remove mole sieve, perform the replacement, and install a new one	2
Maintenance machinist to install window	1
Demonstration technician to clean area	2
Leak checks of plumbing and enclosure	1
Operations technician	5
Radiological control technician	4
Health physicist	1
Total time to do actual job	32

Labor cost for mole sieve change-out is calculated as:

Mound's rate is roughly $85.00 per hour X 32 hours = $2,720.00.

For the 7-year economic life, the mole sieve should not need to be replaced. For the 25-year life, the mole sieve would need to be replaced twice. Each mole sieve replacement will include the cost of the sieve and the disposal cost of a 1,000-Ci contaminated waste item. Since the type A disposal box limit is 1,080 Ci of tritium, the mole sieve will require a dedicated box. The cost of this will be the total of the 55-gallon drum cost, shipping, and disposal fee. From previous work, this cost is $750.00 per drum. For the 25-year life, the mole sieve cost is

2($2,800.00 cost of sieve) + 2($750.00 disposal per sieve)+ 2($2,720 labor cost of change-out) = $12,540.00

From this, the hourly cost for the mole sieve cost is:

$12,540.00/ 22,217 hours (life of unit) = $0.56 per operation hour

See Table C.5 for a list of the item life expectancy for various parts of the Tritium Cleanup Cart unit. The equipment unit rate based on the equipment life (25 years) is $44.42 per hour. Based on the economic life, it is $128.40 per hour for the economic life (7 years).

The total purchase cost of the Tritium Cleanup Cart is given in Table C.4, below, as $400,000.

Table C.4 - Equipment purchase cost for the Tritium Cleanup Cart

Item	Description	Life Expectancy (in years)	Cost (in dollars)
1	Tritium Cleanup Cart Enclosure Assembly	25 plus	$263,600.00
2	Tritium Monitors	25 plus	$33,000.00
3	Control Panel	25 plus	$40,000.00
4	Hygrometer/readout	25 plus	$10,000.00
5	Pressure Transducers	10 plus	$3,000.00
6	Transformer	25 plus	$5,000.00
7	Air Compressor	10 plus	$400.00
8	Metal Bellows Pumps	50,000 hours run time	$30,000.00
9	Flow Controllers	10 plus	$10,000.00
10	Feedthroughs	25 plus	$11,000.00
11	Heat Exchangers	10 plus	$4,000.00
	Total $400,000.00		

From Table C.5, the equipment item replacement unit cost can be calculated. Note that some of the operating items within the Tritium Cleanup Cart have a shorter life than the operational life of the unit as a whole. To arrive at the total equipment cost, the equipment item replacement cost must be included.

For the two operating life options, the expected material costs are shown in Table C.5.

Table C.5 - Cost of replacement based on life

Internal to Tritium Cleanup Cart Item	Replacements for Economic (7-Year) Life	Replacements for Operational (25-Year) Life	Total 25-Year Life Cost
Pressure transducers	0	2	$6,000.00
Air compressor	0	2	$800.00
Flow controllers	0	2	$20,000.00
Heat exchangers	0	2	$8,000.00
Total $34,800.00			

Labor costs are associated with the equipment item replacement material cost. From the previous discussion for the mole sieve, the labor cost for the sieve replacement is taken as a good average for each of the above replacements. Thus, the labor cost associated with the equipment item replacement cost is:

6 items to be replaced X $2,720.00 per item = $16,320

Summing the labor and materials cost, the total cost for the maintenance replacement items is:

$16,320 (labor) + $34,800 (materials) = $51,120

Dividing this by the total operating life of the unit, 22,217 hours, yields a per hour equipment replacement operating cost of $3.05. There is no correction for the economic life calculation.

It is assumed that the Tritium Cleanup Cart will be disposed of as low-level waste at the end of its life. The Tritium Cleanup Cart should fit in a type A box and be below the 1080-Ci limit. Total disposal cost is:

$550 per box + $250 per box shipping and disposal = $800.00

Converting this to an hourly rate, the operational life is:

$800.00/22,217 hours = $0.04 per hour

The economic life is:

$800.00/ 6216 hours = $0.13 per hour

The total equipment cost for the operational life is the sum of the checkrate cost; the mole sieve change-out cost; the equipment item replacement cost; and, the Tritium Cleanup Cart disposal cost. Substituting the actual cost values gives the following:

For the equipment life (25 years), the hourly equipment rate is:

$44.42/hour + $3.05/hour + $0.56/hour (mole sieve) + $0.04/hour = $48.20/hour

For the economic life (7 years), the hourly equipment rate is:

$128.40/hour + 0 + 0 + $0.13/hour = $128.53/ hour

Miscellaneous Costs

The following item represents the total cost of laboratory analysis:

• Swipe analysis cost	60 each	@ $1.82	$109.20

The following items represent supply costs:

• Tape	1 roll	@ $5.00	$5.00
• VCR gaskets	8 each	@ $1.00	$8.00
• Window cleaner	1 each	@ $5.00	$5.00

The total for supplies is therefore $18.00.

The following items represent personal protective equipment costs:

• Gloves	20 pairs	@ $ 0.42	$ 8.40
• Lab coats	2 each	@ $20.00	$40.00

The total cost of personal protective equipment is $48.40.

Unit Rate Calculation

The total operating cost of the Tritium Cleanup Cart (excluding equipment costs) is:

Labor total + lab analysis + supplies + personal protective equipment =
$71,940.00 + $109.20 + $18.00 + $48.40 = $72,115.60

Per equipment operating hour,

$72,115.60/56 operating hours = $1,287.78/Tritium Cleanup Cart operating hour

The total operating cost is $1,287.78 (indicated above) plus the equipment unit rate (as developed above) for the two operational lives. For the equipment operation life (25 years),

$1,287.78 labor/operating hour + $48.20 equipment/operating hour =
$1,335.98 per Tritium Cleanup Cart operating hour

For the total test of 56 hours, the total cost is:

$1,335.98/operating hour X 56 operating hours = $7,4814.88/cleanup

For the equipment economic life (7 years),

$1,287.78 labor/operating hour + $128.53 equipment/operating hour =
$1,416.31/Tritium Cleanup Cart operating hour

For the total test of 56 hours, the total cost is:

$1,416.31/operating hour X 56 operating hours = $79313.36/cleanup

APPENDIX D
ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
BWXTO	BWXT of Ohio
Ci	Curie
D&D	Decontamination and Decommissioning
DOE	U.S. Department of Energy
HTO	tritiated water
ITSR	Innovative Technology Summary Report
LLNL	Lawrence Livermore National Laboratory
LSDDP	Large-Scale Demonstration and Deployment Project
MEMP	Miamisburg Environmental Management Project
OST	Office of Science and Technology
psia	pounds per square inch actual
psid	pounds per square inch differential
PPE	Personal Protective Equipment
RCT	Radiological Control Technician
RWP	Radiological Work Permit
TERF	Tritium Emissions Reduction Facility
USQ	Un-reviewed Safety Question