D&D Technology Report

Russian Electrochemical Decontamination Technology for use in D&D Environments

Deactivation and Decommissioning Focus Area

Prepared for
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Russian Electrochemical Decontamination Technology for use in D&D Environments

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Deactivation and Decommissioning Focus Area

Demonstrated at
V.G. Khlopin Radium Institute
St. Petersburg, Russia

Purpose of this document

This report is designed to provide potential users with the information they need to quickly determine whether this technology would apply to a particular environmental management problem.

This report describes the technology that has been demonstrated with funding from the U.S. Department of Energy's (DOE) Office of Science and Technology (OST). This report presents the results of a demonstration of the technology and identifies the advantages to DOE in terms of technology performance, cost, and effectiveness. Information about commercial availability and technology readiness for implementation is also included.

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.

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SECTION 1
SUMMARY

Technology Summary

The U.S. Department of Energy (DOE) continually seeks effective and safer decontamination technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology sponsors large scale Demonstration and Development Projects (LSDDP) in which developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to DOE projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

In September 1990, the DOE and the Ministry of Atomic Energy for the Russian Federation (MINATOM), signed a Memorandum of Cooperation (MOC) in the areas of Environmental Restoration and Waste Management. This MOC was developed under the auspices of the Umbrella of the Peaceful Uses of Atomic Energy Agreement between the United States and the Soviet Union of Socialist Republics (1972). The MOC called for the creation of the Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM) to oversee and direct bilateral activities.

Several Russian technologies for the decontamination of surfaces have been identified as potentially useful to U.S. site needs. One of these technologies uses electrochemical decontamination methods. A pilot-scale demonstration of this technology has been carried out in Russia, and this report documents that demonstration for potential inclusion in D&D projects in the U.S.

The All-Russian Design and Scientific Research Institute for Complex Power Technology (VNIPIET) and the V.G. Khlopin Radium Institute (KRI) have developed an electrochemical decontamination system (EDS) using a low-ohm electrode combining electrolyte recycling and low-voltage alternating current. This innovative technology uses electrochemical polishing and etching. Radioactive contaminants are removed from metal surfaces through electrochemical dissolution in a circulating aqueous electrolyte. The electrolyte is continuously filtered and passed through a sorbent bed to remove transuranic contaminants and dissolved metals. The electrolyte maybe processed by low-pressure evaporation to recover the formic acid and then treated with phosphoric acid and iron oxide to create a non-leachable solid waste form. This technology is commercially available through Daymos, Ltd., "The Designing-Constructing and Industrial – Inculcating Enterprise" associated with this project (*inculcate* – to implement or introduce in practice).

Advantages of this technology over typical decontamination methods include high decontamination effectiveness and, since the majority of the electrolyte is reused and the rest is solidified, there is no liquid waste generated.

The overall test objective of this demonstration was to determine the performance and cost associated with the Russian electrochemical decontamination technology. Specific objectives were to determine the:

- Ease of technology implementation
- Health and safety enhancements offered by the technology
- Cost data for the use of the technology on large metal objects
- Effectiveness of electrochemical decontamination for decontamination of slightly fixed and removable contamination
- Ease of decontamination assessments from observations by the skilled professionals participating in the demonstration
- Volume and composition of secondary waste
- Reliability of the technology.

Both cost and performance data for the Russian EDS were collected. This included:

- Cost (labor and equipment) of mobilization

- Levels of slightly fixed and loose contamination before and after electrochemical decontamination.
- Time/Cost/Convenience of EDS operation
- Time/Cost of demobilization
- Cost of waste disposal
- Assessment of Health and Safety aspects
- Video record of the performance.

For the Russian electrochemical decontamination technology to prove an effective technology for use by DOE, it would be required to: 1) remove contamination to meet project-specific waste disposal or reuse criteria, 2) produce less waste than competing technologies, 3) be more cost effective, 4) be easier to implement and finally, 5) be safer to operate than competing technologies.

Problem

The Los Alamos National Laboratory (LANL) waste inventory includes approximately 200 "legacy" gloveboxes in temporary storage. These gloveboxes will be processed through the LANL Decontamination and Volume Reduction System (DVRS) and separated into Low Level Waste (LLW, < 100 nCi/g) and transuranic (TRU) waste components. The LLW fraction will be disposed of at LANL, Technical Area 54, Area G, and the TRU fraction will be packaged and certified for ultimate disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. A majority of the gloveboxes to be processed by the DVRS have been classified as TRU.

It will be costly to dispose of items in the TRU category. For LANL, the estimated cost is approximately $140,000 per average sized TRU glovebox. By decontaminating to LLW activity levels, which are acceptable for disposal at the LANL LLW disposal site, disposal cost is reduced to an estimated $6,500 per glovebox, a 95% savings. In addition to cost savings, reduction in waste category has several other benefits. LLW categorized gloveboxes have an immediate path forward to disposition – they may be disposed of in the approved LANL LLW site.

Alternatively, further decontamination enables the reuse of gloveboxes that are not considered obsolete by design. Thereby, all disposal costs could be avoided as well as the cost of replacement.

Traditionally at LANL, gloveboxes were decontaminated by repeatedly scrubbing contaminated surfaces, using nitric acid and polypropylene rags. This method exposes workers to hazardous materials and is also inefficient, as several iterations are needed to adequately decontaminate the glovebox surfaces. Most significantly, a large volume of contaminated rags is generated with each glovebox decontamination. These rags must be disposed of as TRU mixed waste.

How It Works

Electrochemical Decontamination Process

Routine electrochemical decontamination (ECD) consists of polarizing a contaminated metal surface submerged in an electrolyte solution. This process is an effective method to decontaminate metal surfaces if they are not protected with an impermeable coating such as paint. ECD allows the removal of strongly fixed contamination, oxidation, corrosion, and salt deposits, with minimal consumption of electrolyte. Decontamination is accomplished through dissolution of a thin metal surface layer, together with the associated contamination.

The main limitations of routine ECD are the difficulty in preparation of baths for decontamination of large equipment and insufficient dispersal capacity for electrolytes if applied on a localized basis. These limitations may be eliminated through the use of an external electrode. This method utilizes a "microbath," passing the electrochemical process over the contaminated surface.

A promising approach is the use of external low-ohm electrodes incorporating an electrically conductive brush. Each fiber behaves as a microelectrode, closely approaching the surface and at the same time separated from the surface with a thin film of electrolyte. This electrode design provides an opportunity for:

- More uniform decontamination of uneven surfaces
- Decontamination at higher current densities
- The use of ordinary electrolytes such as inorganic acids
- Significantly increased productivity.

The Russian-developed EDS provides for electrolyte recovery from the surface, filtration and sorption to remove contaminants, and recirculation for reuse.

Alternating current is utilized to remove the interfering oxide layer created on stainless steel during the electrolysis process. In addition, alternating current allows chromium from stainless steel to go into solution as a Cr^{+3}, which simplifies later treatment of the liquid radioactive waste. Hydrogen gas release under alternating current conditions is significantly decreased, especially at lower current densities.

Routine ECD technologies generate substantial volumes of waste solution contaminated with radionuclides and dissolved stainless steel (Fe, Cr, Ni). In this scheme, an in-line sorption technology is used to remove the radionuclides and metals from the solution and recycle the electrolyte solution (in this case, formic acid). The process uses an inorganic sorbent, which can be than solidified into a non-leachable waste form.

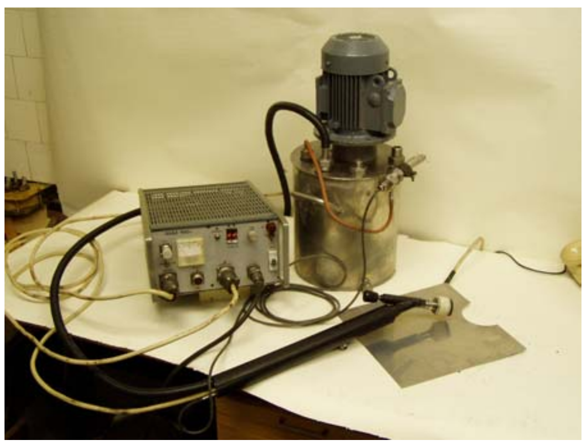

Figure 1 - Russian Electrochemical Decontamination System

Demonstration Summary

In this demonstration, the innovative technology was used to decontaminate a glovebox located at the V.G. Khlopin Radium Institute in St. Petersburg, Russia. The overall goal was to decontaminate the glovebox to very low levels, to meet free release criteria. An additional goal was to determine the effort necessary to decontaminate the glovebox to <50,000 dpm/100cm^2.

This innovative technology was implemented by the Russian EDS. The purpose of the demonstration was to evaluate the decontamination efficiency and the implementation cost for this system. The team recorded operations time from start to finish, total work hours, and expenditures for materials during all phases of the demonstration.

Results

The Russian EDS was successfully demonstrated at the V.G. Khlopin Radium Institute with the following key results:

- Contamination levels were reduced to below 50,000 dpm/100 cm^2 (an administrative limit used to achieve LLW) after two decontamination cycles with the Russian electrochemical decontamination system.

- The Russian electrochemical decontamination system provided decontamination that met the demonstration requirements with an extremely easy-to-use decontamination probe. Rapid decontamination was achieved as the external electrode was brushed across the glovebox interior

- Since the decontamination solution was recovered and the actinide waste can be solidified, no liquid waste was generated.

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The Los Alamos LSDDP website address is: http://www-emtd.lanl.gov/LSDDP/DDtech.html.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition/Technology Definition

Electrochemical Decontamination

ECD utilizing an external electrode provides significant advantages over bath-submersion techniques. Using liquid stream application techniques, a microbath is created at the point of electrolyte contact with the treated surface. These techniques have not experienced wide use because of significant energy dissipation resulting from the electrical resistance of the liquid stream. Alternatively, wads of porous electrically non-conductive material saturated with electrolyte can be used for this purpose. Electrical resistance of these devices is also high, therefore to achieve the desired electrochemical dissolution rate, the process is carried out at 100 - 150 volts. This results in significant energy consumption and discourages the application of the method because of safety concerns.

The most promising approach is the use of external low-ohm electrodes (LOE) with the wad made of electrically conductive fibers. This material is hygroscopic and chemically stable. Each fiber behaves as a microelectrode, closely approaching the surface and at the same time, separated from the surface with a thin film of electrolyte. This electrode design provides an opportunity for more uniform decontamination of uneven surfaces, to decontaminate at higher current densities, to use ordinary electrolytes such as inorganic acids, and to significantly increase productivity.

The conductive fibers have a specific resistance of 10^{-10} ohm cm^{-1}. For comparison, the specific resistance of metals is 10^{-10} ohm cm^{-1}, and for electrolytes is 10^{-15} ohm cm^{-1}. Based on this relationship, the wad material serves as an LOE. In this case, the inter-electrode gap is reduced to a small fraction of a millimeter and its resistance becomes negligibly low (about 10 ohms).

Experimentation has shown that the primary resistance between the LOE and treated surface is the resistance of the wad material and the oxide layer on the metal surface. Due to the hygroscopic nature of the wad material, some amount of electrolyte is always present between it and the treated metal surface, so that the whole transport of charge in the inter- electrode space is achieved by electrochemical reaction. When some individual fibers are dried, the resistance at the fiber-metal interface increases which prevents short-circuiting.

The design of the external electrode is shown in Fig. 2.

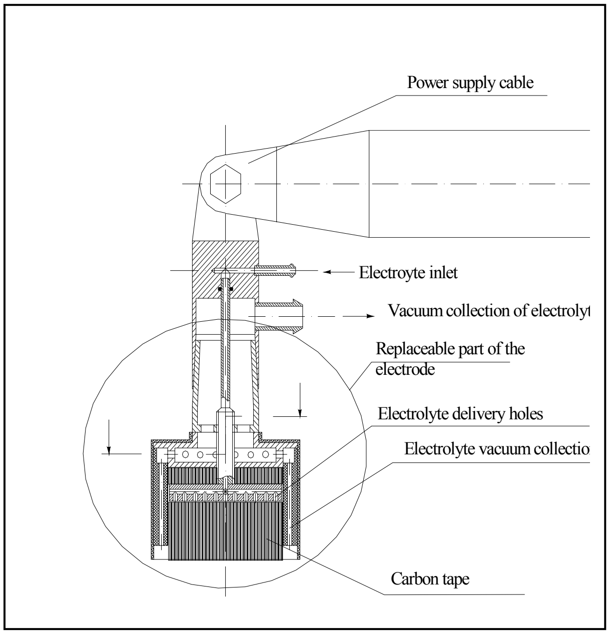


Figure 2 - Design of the External Low-Ohm Electrode

Any inorganic or strong organic acids may be used as an electrolyte in this EDS.

Investigation of the ECD process with direct current has shown that it leads to the formation of a thick electrically non-conductive oxide film on the surface of easily oxidized metals (Ti, Zr, etc.). Such films are destroyed by a reverse polarity impulse. During direct-current ECD, there also exists the issue of hydrogen production and secondary surface contamination.

The decontamination process (anodic polarization) can be carried out in two different modes. The first is etching at a low current density resulting in heterogeneous dissolution around individual metal grains (structural etching). The second, is a mode of homogeneous etching or polishing (at high current density), which is characterized by suppression of structural etching, resulting primarily in dissolution of uneven and rough surface spots. This polishing results in improved surface quality and decreased corrosion, wear, and radionuclide sorption.

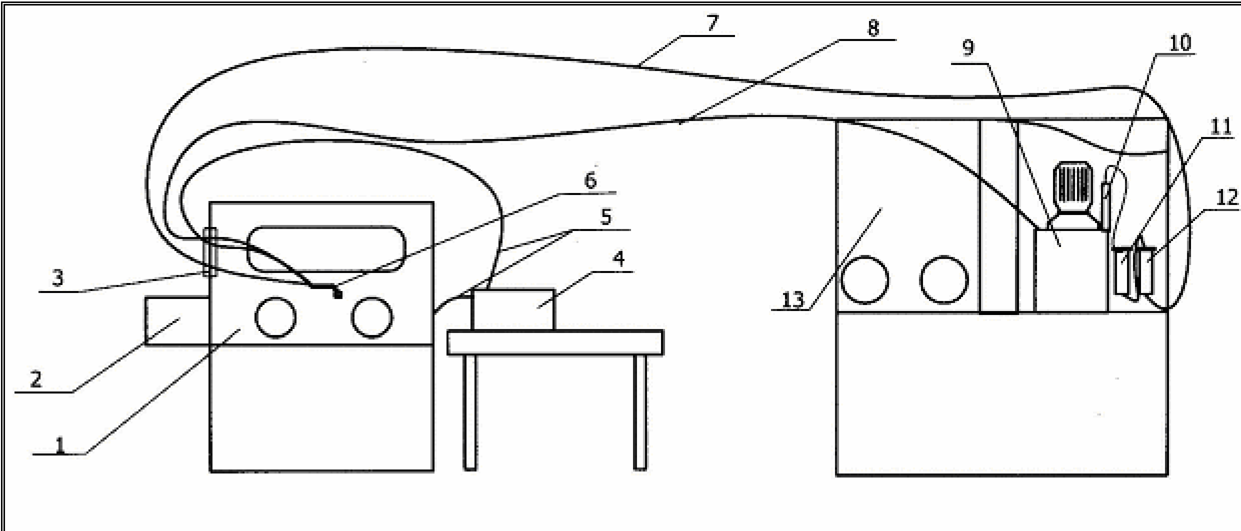
To achieve the required decontamination goals, application of symmetrical or asymmetrical high-frequency alternating current is required. Electric current parameters (voltage, density, wave form, frequency, etc.) and electrolyte composition depend on the material to be decontaminated, contaminant structure, required surface quality, limitations on metal removal and other characteristics. The advantages of alternating current include increased decontamination efficiency with decreased secondary effects.

Selection of the most efficient and economical conditions can be accomplished using alternating current and by adjusting current density and waveform. In most cases, decontamination can be accomplished efficiently with simple power supplies and ordinary electrolytes (common alternating current in medium concentrations of inorganic acids).

The average rate of surface treatment with an ECD unit (external electrode) for flat surfaces is 1,000 – 1,600 cm^2/minute with a power consumption of 2 – 2.7 kW. Decontamination can be carried out with both direct, and alternating current (symmetrical or asymmetrical). The unit provides the ability for electrolyte recovery from the surface, contaminant filtration and sorption, and recirculation.

Investigations using alternating current of different frequencies showed that this type of current removes the oxide film (created with a direct current) from titanium in oxalic acid solutions and to significantly increase the rate of dissolution of oxide film on stainless steel. The specific rate of stainless steel dissolution in 1M nitric acid solution under alternating current is 200 mg/A per hour, and that under direct current is only 120 mg/A per hour. In the case of stainless steel with (symmetrical) alternating current, chromium goes into solution as a cation (Cr^{+3}), which simplifies later treatment of the liquid radioactive waste.

It should be noted, that hydrogen gas release under alternating current conditions significantly decreases, especially with lower current densities.



1- glove box; 2 - forechamber of the box; 3 - flange; 4 - power supply unit ; 5 - electric cables ; 6 - electrode tool ; 7 - electrolyte supply pressure hose; 8 - vacuum hose for electrolyte collection; 9 - tank with electrolyte and water-ring pump; 10 - rough cleaning mechanical filter ; 11 - fine cleaning mechanical filter; 12 - sorption column ; 13 - exhaust hood .

Figure 3 - Russian Electrochemical Decontamination System Equipment Layout

Liquid Radioactive Waste Treatment

The original Russian ECD technology generated substantial volumes of waste solution contaminated with radionuclides and dissolved stainless steel (Fe, Cr, Ni). In this demonstration, a sorption technology was developed to remove the radionuclides and metals from the solution and recycle the decontamination solution. For this demonstration, 3.5-4.0 M formic acid was used and can be processed with up to 80 g/l of Fe, Cr, and Ni. The process uses an inorganic sorbent, which can be then solidified into a non-leachable waste form.

This sorbent effectively extracts U, Np, Pu, and Am. Am is the least extractable element under these conditions. In static conditions, the distribution coefficient (K_d) for Am sorption was 500. In dynamic tests (30 minute contact time) it is possible to pass 100 column volumes of the solution through the column without breakthrough. Under actual conditions, a sorption efficiency down to 90% of the α-activity was observed. The 10% bypass is thought to be caused by Pu absorbed by colloids in the solution.

In the present work, a sorbent size of 0.5-1 mm was used. In-line electrolyte treatment was performed using standard industrial equipment with exchangeable cartridges containing 600 ml of sorbent. During the work, the decontamination coefficient for Am was 500, and for Pu was 40.

To recycle the formic acid, the solution could be evaporated in a rotary evaporator at reduced pressure, in the presence of excess phosphoric acid. This would form soluble acidic phosphates of Fe, Cr, and Ni, and extract the formic acid which could be returned to the decontamination process. The residual phosphate solution could be mixed with the used sorbent and iron oxide, heated to 50 - 80 ^{o}C for 4 hours (until solidified), and then at 120 - 150 ^{o}C for water removal. The manufacture of similar phosphate matrices are widely used in making fire-resistant materials and for joining ceramic blocks. The chemistry of this process is described as follows:

$$Me(COOH)_m + nH_3PO_4 \rightarrow Me(H_2PO_4)_n + mHCOOH$$
$$Me(H_2PO_4)_x + yFe_2O_3 \rightarrow MePO_4 \cdot xFePO_4 \cdot (y-0.5x)Fe_2O_3 + xH_2O$$

where Me represents the metal ion.

In the limiting case, when the sorption column and electrolyte are both fully saturated (up to 80 g/ml, sum of Fe, Cr, and Ni), only 300 ml of 85% H_3PO_4 and ~ 200g of Fe_2O_3 are required to solidify the waste. This process generates 800 ml of solid waste (including the sorbent). Although the recovery and solidification process has been proposed, it was not performed as part of this demonstration.

System Operation

The Russian EDS components may be assembled on the exterior of the glovebox and the electrolyte lines and power cable introduced through a pass-through into the glovebox. Alternatively the equipment may be loaded directly into the glovebox. The system consists of a power supply, electrolyte recirculation system with in-line filter and sorbent bed, external electrode, and connecting cables and hoses (Figure 3).

No surface preparation is required prior to using the system. It is prudent to perform gross decontamination of the glovebox prior to decontamination to reduce contamination loading on the electrolyte and to avoid introducing material into the system that may load the in-line filter and sorption bed.

The external electrode is ergonomically designed with easy angle adjustment and replaceable handle. One or multiple handles can be available to easily reach the various interior glovebox surfaces. Decontamination is accomplished by starting the power supply and the electrolyte pump. Placing the external electrode against the glovebox surface completes the electrolyte recycle loop and initiates the electrochemical decontamination. The external electrode is passed along the surface of the glovebox interior. Minimal pressure is necessary and the external electrode can be passed at a fairly rapid rate (~30 cm (12 in) per second). In practice, there is a visible polishing effect as the external electrode is moved, allowing the operator to identify which portions of the surface have been treated. A small amount of electrolyte does escape the external electrode and dribbles down the inside of the box. This material is collected as the external electrode is passed over that surface. For this reason, the ceiling is typically decontaminated first, followed by the walls and ending with the floor. It is important to note that solution spillage does not contribute to the spread of contamination through the glovebox. Any electrolyte that collects on the floor of the glovebox may be collected using the return line from the external electrode or a separate collection line connected to the electrolyte pump.

In practice, the electrolyte can be re-circulated until the cations (Fe^{+3}, Cr^{+3}, and Ni^{+2}) together reach a concentration of ~10 g/l. This is typically achieved after ~3.5 hours of decontamination. In this case total decontamination time was 52 minutes, which is ¼ of the practical electrolyte life. Thus, the electrolyte can be reused for multiple gloveboxes.

SECTION 3
PERFORMANCE

Demonstration Plan

Demonstration Site Description

The demonstration of the Russian ECD was carried out in October 2002 at the V.G. Khlopin Radium Institute in St. Petersburg, Russia. Each application of the technology was applied to the glovebox surface for the time necessary to provide one decontamination pass across that surface. A single-station glovebox was used for this demonstration (Figure 4). The exterior dimensions of this glovebox are 70 cm (26 in) high by 90 cm (35 in) wide by 70 cm (28 in) deep. The gloveports are 20 cm (8 in) in diameter. The box was previously utilized for research and development of transuranic contaminated waste vitrification. Gross decontamination consisting of wipe-down with dilute nitric acid was performed on the glovebox approximately two years ago. The areas of the glovebox interior surfaces are shown in Table 1.

This glovebox is constructed of stainless steel with a glass window. The exterior of the glovebox is painted, but this surface was not contaminated, nor subject to decontamination during this demonstration. Equipment was introduced into the glovebox through an airlock located on the left side of the box. The glovebox was connected to a ventilation system throughout the demonstration. Room-air was supplied into the box through a small filter located on the top of the box. Prior to starting the demonstration, the interior of the glovebox had been surveyed at various locations for removable contamination (smears) and surveyed for total contamination (direct alpha measurement) to establish initial contamination levels.

Figure 4 - Demonstration Glovebox

Glovebox Surface	Interior Surface Area	
	m^2	ft^2
Left Wall	0.45	4.8
Back Wall	0.63	6.8
Right Wall	0.45	4.8
Floor	0.63	6.8
Front Wall	0.21	2.2
Total	2.37	25.5
Window	0.18	1.9

Table 1 – Demonstration Glovebox Surface Areas

Innovative Technology

The power cable and electrolyte supply and return lines were fed into the glovebox through penetrations on a service panel located on the left side of the glovebox.

No operating procedure has been developed for this Electrochemical Decontamination system. Technical documentation was available for the major system components, comprised of the Russian "Technical Passport" (specifications) and "Instruction of Exploitation" (user guidance). For the demonstration, the Russian EDS was applied to various interior surfaces of the glovebox. Surfaces were treated once, twice, or three times. In between treatment cycles, the surface was rinsed with water and wiped. The surface was allowed to dry, and removable or direct alpha surveys were performed. The Russian EDS was assembled in a fumehood near the glovebox to be decontaminated. The external electrode was introduced into the glovebox through the airlock. Power and electrolyte lines were connected. Once the system was assembled, a readiness check was performed to assure all the necessary equipment and documentation were in-place. An initial decontamination run was performed on the back wall and floor of the glovebox. A leaky electrolyte supply line was observed and repaired, and a loss of vacuum (probably due to a low electrolyte supply level) was detected and resolved. Then the left wall and right wall surfaces were decontaminated. A removable contamination survey was then performed. This demonstration was performed using 4M formic acid as the electrolyte and 400 Hz alternating current at a maximum of 17 volts and a maximum of 30 amps. This achieved a current density of 1-5 A/cm^2.

Subsequently, second and third decontamination cycles were performed. Not all glovebox surfaces were decontaminated on each cycle. The surfaces were decontaminated as indicated in Table 2.

The time necessary to accomplish that decontamination pass is shown in Table 2.

Glovebox Surface	Decontamination Time (minutes)		
	Cycle 1	Cycle 2	Cycle 3
Left Wall	2	4	
Back Wall	5	8	10
Right Wall	3		
Floor	3	9	3
Front Wall			5
Total	13	21	18

Table 2 – Glovebox Surface Decontamination Effort

Demonstration Objectives

The principal goal of the demonstration (Reference 1) was to establish the Russian EDS performance and cost data. A successful demonstration is based on the innovative technology's ability to achieve the following objectives:

- Assess the ease of technology implementation
- Evaluation of health and safety enhancements offered by the technology
- Develop cost data on the use of ECD on large metal objects
- Demonstrate effectiveness of ECD for decontamination of slightly fixed and removable contamination
- Develop ease of decontamination assessments from observations by the skilled professionals participating in the demonstration
- Document information on volume and composition of secondary waste
- Assess the reliability of the technology.

Results

- **Assess the ease of technology implementation**

  Once the system was assembled and started, the operation was observed to be very easy. Rapid movement of the external electrode across the metal surface provided decontamination. If any electrolyte dripped it could be easily picked up by the external electrode.

- **Evaluation of health and safety enhancements offered by the technology**

  The Russian EDS allows implementation of the technology inside the glovebox with an intact ventilation system. This minimizes the potential for release of contaminants from the glovebox. The relatively rapid application of the process to the glovebox surface results in reduced exposure time for the operators. The low voltage (17 volt maximum) used in this process does not present any electrical shock hazard. Finally, the relatively low hydrogen gas production rate (1 l/hr at 30A) is easily accommodated by the glovebox exhaust, eliminating the potential for combustible atmosphere buildup. Liquid volume is limited to 3.5 liters and limited contamination levels eliminate criticality concerns.

- **Develop cost data on the use of ECD on large metal objects**

  The time to implement the technology during the mobilization, application and demobilization phases may be seen in Table 3. For a detailed assessment of the cost to implement this technology, see Section 5.

Mobilization	
Activity	**Hours**
Characterize glovebox surfaces	30 min
Set up equipment in controlled area	1.5 hr
Prepare electrolyte and nitric acid	45 min
Debug equipment and hoses	10 min
Subtotal	2.9 hr
Monitoring, Sampling, and Testing	
Decontaminate Floor	15 min
Decontaminate Right Wall	3 min
Decontaminate Back Wall	23 min
Decontaminate Left Wall	6 min
Decontaminate Front Wall	5 min
Characterize glovebox surfaces	1.2 hr
Subtotal	2.1 hr
Demobilization	
Drain and Disassemble System	65 min
Remove System	1.5 min
Bag Secondary Waste	25 min
Process Liquid Waste	
Subtotal	3.0 hr
Total	8 hr

Table 3 – Electrochemical Decontamination System Demonstration Activities

- **Demonstrate effectiveness of ECD for decontamination of slightly fixed and removable contamination**

  Before starting the demonstration, both direct readings and smear samples were taken on representative interior surfaces of the glovebox. After each step of the technology application, additional measurements were taken on the treated surfaces. See Appendix D for detailed results. Tables 4 and 5 summarize data for the locations at which sufficient data was collected to characterize the decontamination effectiveness of the EDS. Figures 5 and 6 show this information graphically.

Glovebox Surface	**Removable Contamination Levels (dpm/100cm^2)**			
	Initial	**Cycle 1**	**Cycle 2**	**DF**
Left Wall	32,000	4,000		8
Back Wall	21,000	10,000	1,200	17
Right Wall				
Floor	35,000	8,700	1,500	23
Front Wall	230,000	34,000		7
average	80,000	14,000	1,300	**14**
DF		5.7	5.6	

Table 4 – Glovebox Removable Surface Decontamination Results

Glovebox Surface	Total Contamination Levels (dpm/100cm^2)			
	Initial	Cycle 1	Cycle 2	DF
Left Wall				
Back Wall	44,000	7,300	6,600	7
Right Wall				
Floor	120,000	17,000	4,600	26
Front Wall	900,000	150,000		6
average	350,000	58,000	5,600	**13**
DF		6.0	2.2	

Table 5 – Glovebox Total Surface Decontamination Results

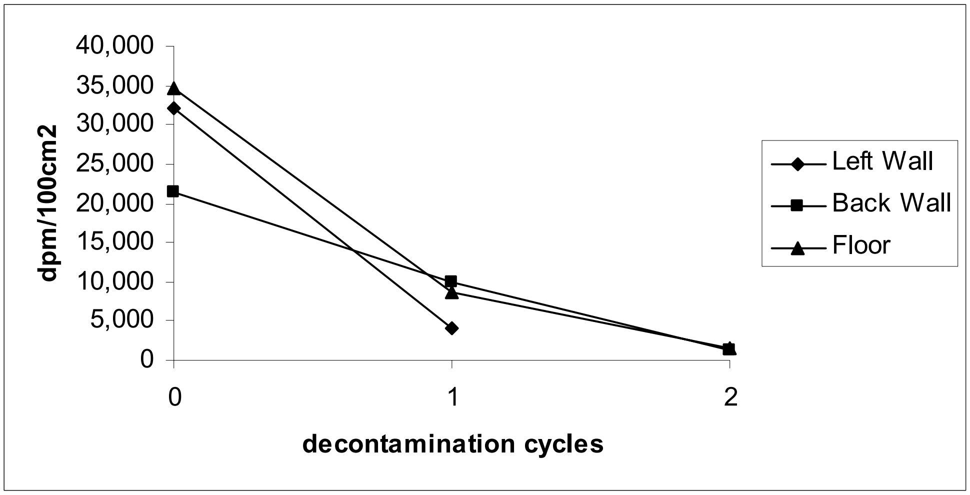


Figure 5 - Removable Decontamination Performance

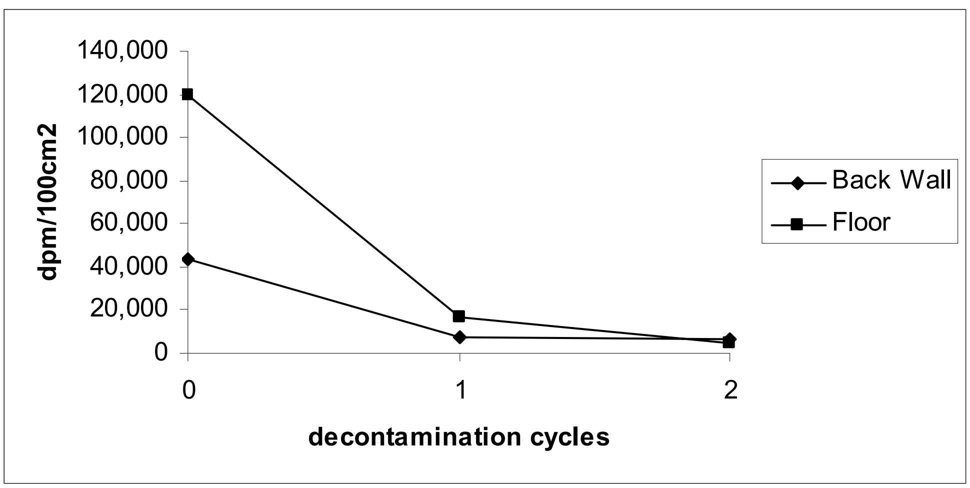


Figure 6 - Total Decontamination Performance

The goal of this demonstration was to determine if the Russian EDS is effective for decontaminating gloveboxes from the initial levels indicated in Table 4 to a surface contamination level of 100 dpm/100cm^2 total (fixed + removable) contamination, consistent with free release criteria under 10 CFR 835. An additional goal was to achieve a level of 50,000 dpm/100cm^2 (or less), consistent with LANL LLW operational requirements.

It was determined that the Russian EDS could decontaminate the glovebox surfaces to the LLW target in no more than two passes. An alpha probe was utilized to verify that each treated area was decontaminated below 50,000 dpm/100cm^2.

An additional decontamination pass was performed to obtain data for the glovebox free release objective. This level was not achieved. The results of this demonstration are reported in Tables 4 and 5. From this data, it can be seen that additional applications of this decontamination technology are necessary to achieve this low contamination level.

- **Develop ease of decontamination assessments from observations by the skilled professionals participating in the demonstration**

Observation of the operation indicated that the system is easily operated inside the glovebox. The external electrode did not require any significant pressure (against the glovebox wall) during operation and did not provide any friction making it hard to push. The external electrode head was mounted on a moveable and extendable handle, allowing easy adjustment to the angle necessary to properly treat each surface. This resulted in an ergonomically appropriate operation.

- **Document information on volume and composition of secondary waste**

The Russian EDS produced a liquid waste that was then treated to recycle the electrolyte (formic acid) and create a non-leachable solid waste form. At the end of the demonstration, a total of 800 milliliters of solid waste was created. Since the Russian EDS cannot be used to decontaminate the non-conductive glass window, these areas must be decontaminated with an acid wipe down step. It is estimated that approximately 0.33 m^2 (3.6 ft^2) of the glovebox surface is comprised of the glass window. Based on previous experience, wipe down of the window would result in a total of approximately 0.0073 cubic meters (1.9 gallons) of waste rags.

Contaminated rags were generated during the rinse and wipe process prior to direct alpha measurements. Rags resulting from wiping 0.5 m^2 were generated during this step. This is assumed to result in an additional 0.01 cubic meters of TRU waste rags requiring disposal.

No other waste was produced during the demonstration. Contaminated PPE generated during this operation were placed in the routine laundry streams for the facility and were not included in the waste estimates developed for this demonstration.

- **Assess the reliability of the technology**

The equipment used for this demonstration could be characterized as a laboratory scale demonstration. Adjustment of electrolyte flow was performed by hand and one tubing connection required attention to repair a leak. It is assumed that these problems would be eliminated in an engineered system specifically implementing this technology.

This process does not lend itself to quantitatively uniform decontamination. Application of the external electrode on the surface provides for the possibility of overlap or gaps between passes and the exact time of treatment on any given surface element is not carefully controlled. The surface area typically covered by a direct alpha measurement (50 – 100 cm^2) and the use of multiple measurements will average these potential nonuniformities and provide measurements useful to evaluate if the decontamination criteria has been achieved.

As with most other decontamination processes, this process does not provide an easy method to determine when an adequate decontamination level has been achieved. It is necessary to discontinue decontamination, rinse and wipe the surface to remove any residual removable contamination, allow the surface to dry, and perform direct alpha contamination measurements.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

This Russian electrochemical decontamination system is not limited to use at Los Alamos, but is applicable for use throughout the DOE nuclear complex - where hundreds of gloveboxes are currently located at six different facilities. The technology has also be used in nuclear power plants and fuel reprocessing facilities to clean contaminated equipment; resulting in reduced waste stream volume, reduced radiation exposure to workers, and cost savings. This technology has the potential for application to other contaminated materials including tools, machinery, piping, and metal components; thus extending the useful life of these products.

Competing Technologies

Two electrochemical technologies have been identified that can be compared to the Russian EDS. These are the LANL Electrolytic Decontamination Technology and an electrochemical decontamination system developed by ADA Technologies.

The LANL Electrolytic Decontamination System
The LANL EDS (Reference 2) replaces older, less efficient, glovebox decontamination methods at LANL with a closed-loop cleaning system. A uniform electrolyte etch is achieved at low voltages and currents in combination with controlled solution chemistry to rapidly strip a few microns from the metal surface, resulting in the removal of surface contamination. Application to the contaminated surface is by means of a detachable hand fixture sealed to the surface by vacuum. The electrolyte solution flows through the fixture and is monitored and automatically adjusted to keep the pH at a high level promoting the formation of metal hydroxides, which precipitate out of solution. Solution recycle is accomplished by utilizing ultrafiltration with in-line separation of these hydroxides that include the radiological components. This recycle and filtration technique minimizes aqueous process waste and results in minimal solid/radioactive wastes trapped in the disposable in-line filter cartridges. This process has been shown to reduce plutonium and americium contamination by more than 6 orders of magnitude in other applications, permitting the gloveboxes to be disposed of as LLW or reused on location.

The ADA Electrodecontamination System
ADA's Electrodecontamination System (Reference 3) is a self-contained unit approximately the same size as a small vehicle battery charger. In this technology, electrolyte gel is pumped from a small reservoir to a hand-held scrubbing fixture that is fitted with a disposable, non-conductive and highly porous abrasive pad. When the gel-saturated pad is brought in contact with a conductive contaminated surface, electrical current passes from the surface, through the electrolyte, into a protected terminal within a reservoir located in the scrubbing fixture. A removable electrolyte film is left behind, encapsulating the contaminants. The system has yet to be demonstrated on a plutonium contaminated glovebox, so there can be no direct comparison with this system to the Russian EDS. Despite the lack of sufficient decontamination effectiveness data, this system could offer the following benefits over competing technologies:

- Gel remains in place on walls and ceilings without running or spreading contamination
- The system is small, and all system components may be placed with a glovebox
- The system is inexpensive
- No hazardous offgases are generated during its use
- No liquids are used
- Waste includes only contaminated electrolyte pad.

One disadvantage of this system could be that the protective coating may need to be removed (manually) if reuse of the glovebox is intended.

Patents/Commercialization/Sponsor

The Russian ECD technology was developed by VNIPIET/KRI under the MOC in the areas of Environmental Restoration and Waste Management between the United States and the Soviet Union of Socialist Republics (1972), coordinated by the JCCEM. The next step in commercialization of this technology would be the development of a detailed cost evaluation and an additional demonstration within the DOE/MINATOM JCCEM Program. VNIPIET/KRI can fabricate a unit, deliver and train personnel to use the technology. Interested parties should address this with the contacts listed earlier in this report.

SECTION 5
COST

Methodology

The objective of the cost analysis is to provide interested parties with a cost estimate for implementation of the Russian EDS on a production scale at a DOE site. This cost estimate considers the costs associated with the technology on a per glovebox basis. For this cost estimate it is assumed that the site will purchase the equipment necessary to construct a Russian EDS.

The Russian EDS technology was demonstrated under controlled conditions (i.e., an in-place glovebox), which facilitated observation of the work activities and the typical duration of each activity. To estimate realistic DOE facility implementation costs, additional assumptions were required. This cost analysis also characterizes the technology based on a unit processing cost.

Key assumptions for the cost estimate are listed below. Additional assumptions and details about the cost analysis are presented in Appendix C.

- For the demonstration, the technology was used to decontaminate one glovebox. As shown in Table 1, the glovebox decontaminated by this technology, has an internal area of approximately 2.3 m^2 (25 ft^2). To arrive at an implementation cost per glovebox, the time and material costs required to apply the technology was normalized to a unit square meter.
- It is assumed that a work team consists of two workers, and one Radiological Control Technician (RCT, present only when performing surveys and introducing equipment into the glovebox line).
- It is assumed that the Russian EDS has been assembled and tested and is functional. There will be no downtime due to equipment malfunctions and testing.
- A DOE site, such as LANL, will purchase all equipment necessary for each Russian EDS for deployment in a radiologically contaminated D&D operation and perform any pretreatment, prior to removing a glovebox from service prior to packaging.
- No overhead factors were applied to other direct costs.
- Fully burdened labor rates for LANL personnel were used in the estimate.
- Gloveboxes are assumed to be free of equipment, and no cost to clean or move equipment out of the glovebox was included.
- The protocol for operating the Russian EDS was assumed to consist of 1) glovebox modifications (if required), 2) system component assembly, 3) introduction of system components into glovebox line, 4) decontaminating the glovebox internal surfaces, 5) removal of the system for later use on other gloveboxes, 6) liquid waste processing.
- No additional procedural costs were involved.

Cost Analysis

To develop estimates for decontamination of gloveboxes to the LLW target (<50,000 dpm/100 cm^2), a cost per unit area (m^2) basis was chosen. With a total surface area of 2.37 square meters (25.5 ft^2) for the demonstration glovebox, these costs can then be reported in a normalized fashion. Activities were grouped under higher level work titles per the work breakdown structure shown in Reference 4, Hazardous Toxic, Radioactive Waste Remediation Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS) (U.S. Army Corps of Engineers, 1996).

Using the demonstration costs as a basis, estimates were developed for mobilization, sampling and testing, demobilization and disposal costs for the Russian EDS technology.

The innovative technology reached the LLW target with two decontamination cycles. The combined time for the first two decontamination cycles represents the time that would be required to decontaminate the entire glovebox to the LLW target.

The cost of one Russian EDS unit is approximately $11,496. This cost, amortized over ten glovebox decontaminations, except for the in-line filters and sorbent which were amortized over four gloveboxes (based on operational experience) is $1,182. Included in this total are the cost of the electrolyte, the costs to fabricate the system components such as the custom-built pump and power supply and the costs to pre-assemble and pre-test the system. Additional estimated costs for electrolyte solution and rags needed for decontamination of the windows were added to the cost estimate. The total cost for the initial glovebox is approximately $6,886, with incremental costs of approximately $598 for each additional glovebox. Figure 7 displays the implementation cost for the innovative technology to LLW disposal levels.

Figure 8 shows the dependency of the glovebox cost on the number of gloveboxes processed for one EDS unit located to service ten gloveboxes. This chart assumes that one unit will be used to decontaminate a line of gloveboxes, where the unit remains outside the glovebox and the hose and electrical connections are routed through the glovebox to adjacent gloveboxes. For example, if four gloveboxes are to be decontaminated using one unit, there would be the cost of one mobilization, four applications and one demobilization.

Cost Conclusions

These cost estimates provide a reasonable estimate for implementation of the Russian EDS (innovative technology). From the cost estimate section of this report, the costs for each technology to decontaminate the glovebox to the <50,000 dpm/100cm^2 are:

Russian EDS $2,905 per square meter = $270 per square foot.

The Russian EDS may be more cost effective if larger areas are to be decontaminated with one mobilization. For example, if multiple gloveboxes are arranged such that the Russian EDS can be used on the first glovebox and moved to successive gloveboxes without demobilization, the Russian EDS technology becomes more cost effective, as demonstrated by Figure 8.

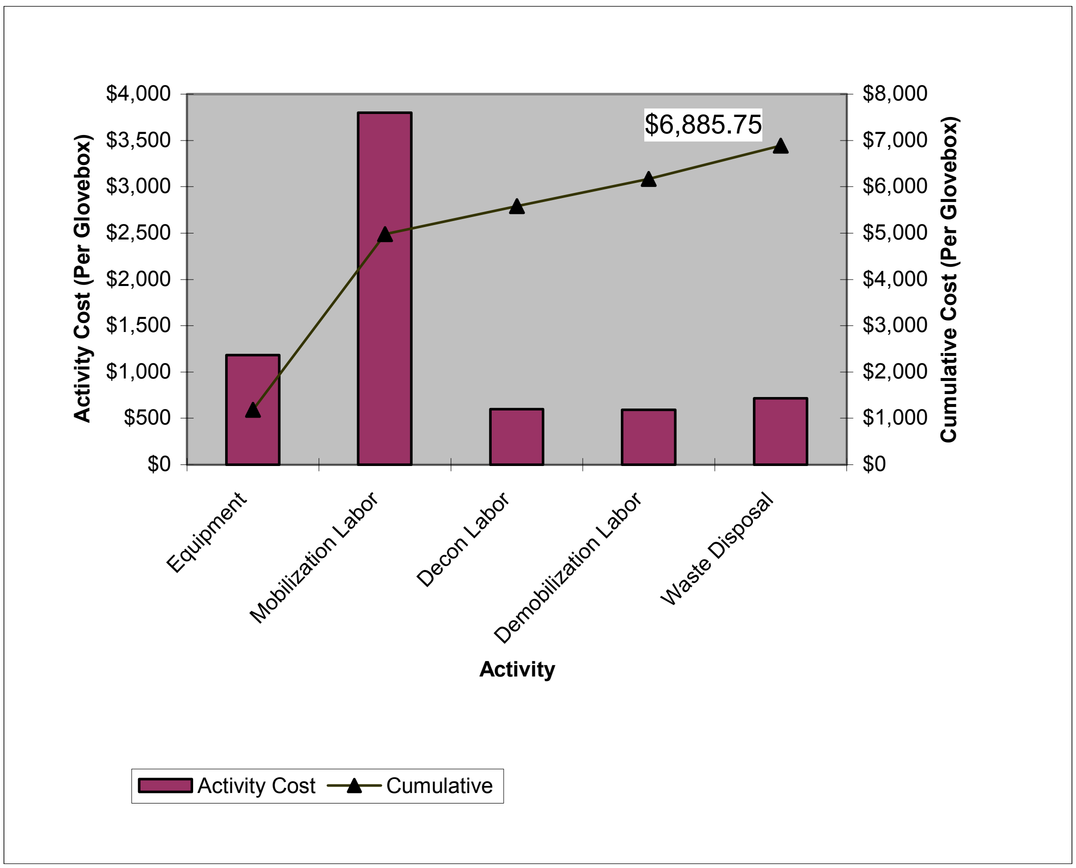


Figure 7 – Glovebox Costs for Russian Electrochemical Decontamination System

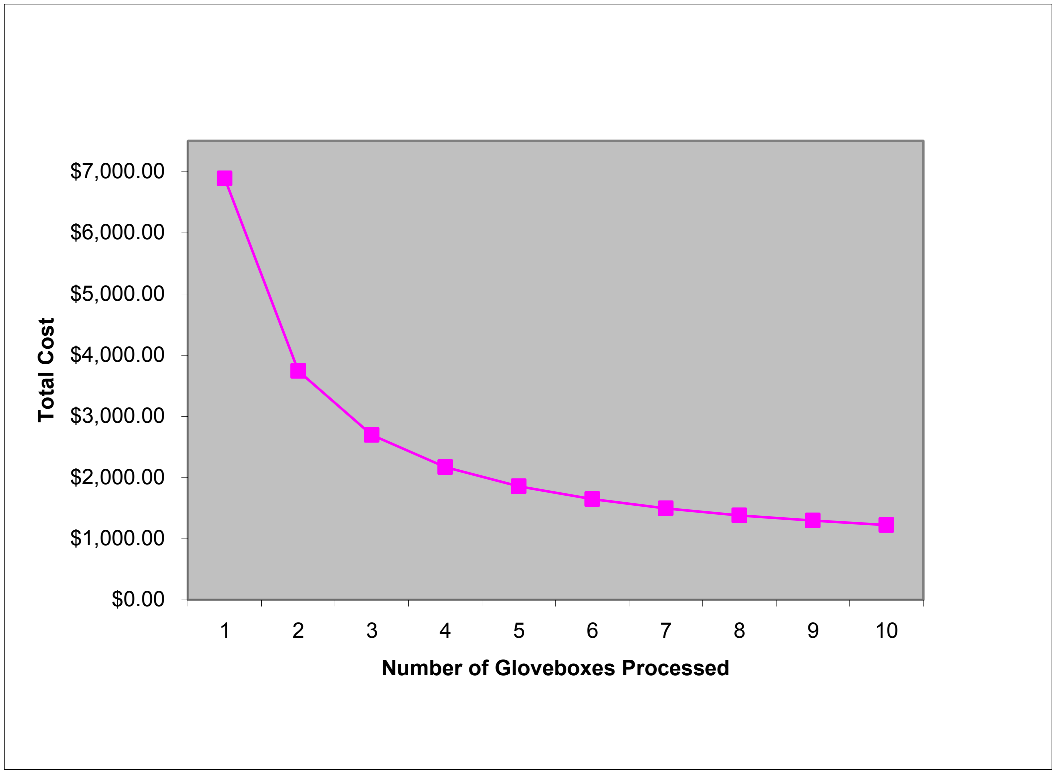


Figure 8 – Multiple Glovebox Cost Determination for Russian EDS

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Regulations for using the Russian EDS are dependent upon each DOE Site's requirements, including:

- Radiological controls
- Nuclear criticality controls
- Nuclear operations requirements
- Waste acceptance criteria.

Safety, Risks, Benefits, and Community Reaction

Worker Safety

Operators of the Russian EDS must be trained in the proper procedures for glovebox work and safe operation of the decontamination system.

In accordance with As Low as Reasonably Achievable (ALARA) principles, workers must minimize potential exposure to radioactive and hazardous materials by proper planning to minimize time spent in work areas, maximize distance between them and hazardous substances, and utilize radiological shielding where appropriate.

Community Safety

Community safety is not adversely affected by operation of the Russian EDS. The system will not significantly increase the background radiation in an area. In fact, operation of the system (and disposal of the resulting waste) will reduce the risk to the community by reducing the amount of contamination available for dispersion in case of a facility accident. Transportation of the unit poses no risk to the public.

Environmental Impact

There is no negative impact and a potential positive impact to use of the Russian Electrochemical Decontamination System since it has the capability to significantly reduce contamination levels before glovebox disposal.

Socioeconomic Impacts and Community Reaction

There are no socio-economic impacts associated with the Russian EDS. Community reaction is likely to be positive since less disposable actinide waste will be handled during disposal.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The Russian EDS technology could be made available for use at DOE sites. The technology is commercially available from Daymos, Ltd. through the Technical Contacts identified in this report. The following should be considered when selecting the Russian EDS as a decontamination technology:

- It is recommended that Russian personnel demonstrate proper use of the system before application
- The site using the Russian EDS must have TRU waste disposal capability for disposal of the solidified sorbert and span filters.
- Typically the in-line filter is replaced once every four gloveboxes
- It is prudent to perform gross decontamination of the glovebox prior to decontamination to reduce contamination loading on the electrolyte and to avoid introducing material into the system that may load the in-line filter and sorption bed.
- There is no need to wipe down surfaces before applying electrolyte as solutions will be collected by the system and recovered with blow down.
- Adequate electrolyte flow must be maintained through the external electrode when in contact with the surface to be decontaminated
- Gloveboxes must have adequate ventilation to dilute and exhaust any hydrogen created.

Technology Limitations and Needs for Future Development

The Russian EDS demonstrated that it will accomplish the task for which it was designed. It provides DOE a simple means of reducing contamination levels within gloveboxes that will be reused, or disposed of. It is limited to the following:

- Electrochemical processes may only be applied for removing radionuclide contamination from conducting surfaces, such as iron-based alloys (including stainless steel), copper, aluminum, lead and molybdenum.
- The external electrode can be used to decontaminate convoluted surfaces with complex geometries. Thus, it is capable of decontaminating most (conductive) surfaces encountered in glovebox decommissioning.
- Another means of decontamination must be used for nonconductive surfaces. Nitric acid wipe was assumed for this cost analysis.
- An additional demonstration should be performed on a glovebox that is contaminated to higher levels (several million dpm/100cm^2), typical of those found in DOE facilities.

Technology Selection Considerations

- An adequate pass-through must be available to introduce the electrolyte lines and electric cable to connect the external electrode to the rest of the system
- To be used in a D&D environment, the site must have the capability to process the liquid waste (into the non-leachable phosphate based ceramic) and ultimately dispose of this material
- The technology has been demonstrated on a laboratory scale. The equipment has not been engineered and “packaged” specifically for this application. Some additional work will be necessary.

APPENDIX A

REFERENCES

1. “Project Specific Test Plan for the Electrochemical Decontamination Technology,” IT Corporation, July 2002.

2. “LANL Electrolytic Decontamination Technology for use in D&D Environments,” Innovative Technology Summary Report, U.S. Department of Energy, Office of Environmental Management, Office of Science and Technology, October 2002.

3. “Electrodecontamination Becomes Practical,” ADA Technology (Available from ADA).

4. “Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure,” Prepared for the U.S. Department of Energy, January draft, U.S. Army Corps of Engineers, 1996.

APPENDIX B
ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DF	Decontamination Factor
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DVRS	Decontamination and Volume Reduction System
ECD	Electrochemical Decontamination
EDS	Electrochemical Decontamination System
HTRW RA WBS	Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure
JCCEM	Joint Coordinating Committee for Environmental Restoration and Waste Management
K_d	distribution coefficient
KRI	V.G. Khlopin Radium Institute
LANL	Los Alamos National Laboratory
LLW	Low Level Waste
LOE	Low-Ohm Electrode
LSDDP	Large-scale Demonstration and Deployment Project
MINATOM	(Russian) Ministry of Atomic Energy for the Russian Federation
MOC	Memorandum of Cooperation
nCi/g	nanocuries per gram
OST	Office of Science and Technology
RCT	Radiation control technician
TMS	Technology Management System
TRU	Transuranic
VNIPIET	All-Russian Design and Scientific Research Institute for Complex Power Technology
WBS	Work Breakdown Structure

APPENDIX C
TECHNOLOGY COST DETERMINATION

Basis of Estimated Cost

The activity titles shown in this cost analysis for implementation were derived from observation of the work performed during the demonstration and from a reasonable estimate of the level of effort required for implementation at DOE sites. In the estimate the activities are grouped under higher level work titles according to the work breakdown structure shown in "Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS)" (U.S. Army Corps of Engineers, 1996, Reference 4). The HTRW RA WBS was developed by an interagency group, and is used in this analysis to provide consistency with the established national standards.

The stated goal of this demonstration was to determine if the Russian EDS is an effective technology for decontaminating gloveboxes from the initial levels indicated in Table 3 to a surface contamination level of 100 dpm/100cm^2 total (fixed + removable) contamination, consistent with free release criteria under 10 CFR 835. An additional goal was to achieve a level of 50,000 dpm/100cm^2 (or less), consistent with LANL LLW operational requirements.

The costs shown in this analysis are computed from observed duration and hourly rates (LANL) for the crew, supplies, and equipment.

The costs for the technology were based on the effort to decontaminate an operational glovebox, complete with exhaust ventilation and power and electrolyte line pass-throughs, at the V.G. Khlopin Radium Institute in St. Petersburg, Russia. The overall surface area treated inside the glovebox was 2.3m^2 (25 ft^2). The time intervals for the various tasks performed for the baseline technology were recorded to develop the estimated cost for decontaminating the glovebox. The initial EDS application involved monitoring with an alpha probe after completion of each decontamination cycle to determine if the surfaces were decontaminated to below the LLW target. An additional application of the EDS was performed to determine to what level it could be decontaminated within a reasonable timeframe.

Activity Descriptions

Mobilization and Preparatory Work (WBS 33.1.01)

Mobilization of Equipment – Mobilization of equipment includes building one Russian EDS, and the necessary chemicals. The Electrochemical decontamination system, including all system components, has been quoted by VNIPIET/KRI personnel to be approximately $11,695. This cost was adjusted by a factor of 0.10 (0.25 for the in-line filter) to effectively amortize it over the decontamination of ten similar gloveboxes.

Mobilization of Personnel – For this cost estimate, it was assumed that mobilization begins at the point where the innovative technology system is assembled for use. The system must be set-up in the room, the external electrode introduced into the glovebox, and the hoses and electrical cable run into the glovebox and connected. According to LANL procedures, two technicians (two-man rule) and one RCT are required to introduce equipment into the glovebox line. It is assumed that another DOE site implementing these technologies will have similar requirements. Once the equipment has been introduced into the glovebox, two technicians connect the system, connect electrical cords to nearby service receptacles, and then add electrolyte to the system.

Submittals/Implementation Plans – Plans and permits were assumed to be complete prior to the start of work and will not be considered in this cost estimate.

Monitoring, Sampling & Testing (WBS 33.1.02)

Two technicians are required to operate the unit. An RCT is present to take direct alpha readings, observe smears as they are taken, remove them from the glovebox line, and count the smears.

The results presented in Tables 4 and 5 show that the target decontamination level of 50,000 dpm/100 cm^2 was achieved after two decontamination cycles with the innovative technology. The total time required to complete the three decontamination cycles on the glovebox using the innovative technology was approximately one hour of decontamination time. Additional time and material costs, for wiping down the windows with nitric acid, were included in the estimate.

Demobilization (WBS 33.1.21)

Equipment Decontamination and Release – For this estimate, it is assumed that equipment inside the glovebox (electrode and connecting wire and hoses) will ultimately be packaged for disposal as waste instead of being decontaminated. A prorated (for ten gloveboxes) cost for disposal of the EDS unit as LLW was included in the estimate. Also, disposal costs for waste rags created during direct alpha survey and the window wipe-down process were included.

Waste Generation (WBS 33.1.18)

Approximately 800 milliliters (0.0283 ft^3) of solid waste would be generated from the spent sorbent. Waste disposal of this material would incur a negligible cost. The formic acid could be recycled for later use.

Cost Estimate Summary

The cost analysis details are summarized in Table C-1. The table breaks out each equipment and labor cost.

TABLE C-1 Russian Electrochemical Decon. System Estimated Implementation Cost							
TITLE	**LABOR**	**MATERIALS**	**LABOR QUANTITY**	**UNIT OF MEASURE**	**UNIT COST**	**QUANTITY**	**SUBTOTAL**
Mobilization and Preparatory Work (WBS 33.1.01)							**$4,980.55**
Materials							**$1,182.22**
Electrochemical Decontamination Equipment - amortized over 10 gloveboxes							***$1,182.22***
	Circulation Pump/Electric Motor			Lump	$6,100.00	0.10	$610.00
	Filter			Lump	$16.00	0.25	$4.00
	Sorbent			Lump	$100.00	0.25	$25.00
	Power Supply			Lump	$5,000.00	0.10	$500.00
	Pipe/Tubing/Fittings			Lump	$73.43	0.10	$7.34
	Reservoir			Lump	$50.00	0.10	$5.00
	External Electrode			Lump	$150.00	0.10	$15.00
	Assembly Tools			Lump	$6.67	0.10	$0.67
	Formic Acid			L	$13.21	0.88	$11.56
	Nitric Acid			L	$13.21	0.13	$1.65
	Rags			Bag	$2.00	1.00	$2.00
Labor							**$3,798.33**
Technicians							***$3,744.58***
	Training site personnel		2	Hour	$107.50	15.00	$3,225.00
	Collect smears & direct measurements		1	Hour	$107.50	0.50	$53.75
	Set up equipment in hot area		2	Hour	$107.50	0.50	$107.50
	Load equipment into glovebox		2	Hour	$107.50	0.17	$35.83
	Prepare glovebox wiring		2	Hour	$107.50	0.17	$35.83
	Prepared 3.5L of electrolyte		1	Hour	$107.50	0.25	$26.88
	Prepare 1/2 L of nitric acid solution		1	Hour	$107.50	0.25	$26.88
	Move electrolyte and nitric acid into room		2	Hour	$107.50	0.08	$17.92
	Electrolyte into system and nitric acid into glovebox		2	Hour	$107.50	0.17	$35.83
	Check system for leaks		2	Hour	$107.50	0.17	$35.83
	Prepare wiring inside glovebox		2	Hour	$107.50	0.25	$53.75
	Connected wiring outside glovebox		2	Hour	$107.50	0.08	$17.92
	Complete assembly of decon unit inside glovebox		2	Hour	$107.50	0.33	$71.67
Radiological Control Technicians(RCTS)							***$53.75***
	Contamination measurements		1	Hour	$107.50	0.50	$53.75
Monitoring, Sampling & Testing (WBS 33.1.02)							**$598.31**
Labor							**$598.31**
Technicians							***$465.73***
	Decon floor		2	Hour	$107.50	0.25	$53.75
	Decon right wall		2	Hour	$107.50	0.05	$10.75
	Decon back wall		2	Hour	$107.50	0.38	$82.42
	Decon left wall		2	Hour	$107.50	0.10	$21.50
	Decon front wall		2	Hour	$107.50	0.08	$17.92
	Wipe down windows with nitric acid		2	Hour	$107.50	0.07	$14.23
	Collect smears & direct measurements		2	Hour	$107.50	1.23	$265.17
Radiological Control Technicians(RCTS)							***$132.58***
	Contamination measurements		1	Hour	$107.50	1.23	$132.58
Demobilization (WBS 33.1.21)							**$591.25**
Labor							***$591.25***
Technicians							$591.25
	Disassemble system		2	Hour	$107.50	1.00	$215.00
	Drain electrolyte		2	Hour	$107.50	0.08	$17.92
	Mop up		2	Hour	$107.50	1.50	$322.50
	Bag waste		2	Hour	$107.50	0.17	$35.83
	Remove wastes		2	Hour	$107.50	0.25	$53.75
Waste Generation (WBS 33.1.18)							**$715.64**
	Waste rags as TRU waste			cubic meter	$34,550.00	0.0173	$597.72
	Cemented waste			cubic meter	$34,550.00	0.002	$82.92
	Decon unit disposal (LLW-amortized over 10 gloveboxes)			Lump	$350.00	0.100	$35.00
TOTAL							**$6,885.75**

APPENDIX D
DEMONSTRATION SURVEY INFORMATION

Electrochemical Decontamination Demonstration Table D-1

	Initial Conditions		First Cycle			Second Cycle			Rinse			Third Cycle			Rinse	Final Conditions	
Surface	Removable cpm/cm^2	Direct cpm/cm^2	Decon minutes	Removable cpm/cm^2	Direct cpm/cm^2	Decon minutes	Removable cpm/cm^2	Direct cpm/cm^2	Decon minutes	Removable cpm/cm^2	Direct cpm/cm^2	Decon minutes	Removable cpm/cm^2	Direct cpm/cm^2	Decon minutes	Removable cpm/cm^2	Direct cpm/cm^2
Floor = 0.63m^2			3	ineffective decon		9	1st successful decon cycle					3				2nd successful	
	360	907		360			35	252			19.8					7.2	15.3
	70	342.5						108									54
	130	760						27									9.9
	107.5	175						234								8.1	17.1
	200			600			52.5									7.2	
		245						36									19.8
		1160						72									198
Front Wall = 0.21m^2												5				1st successful	
	1170												216			59.4	
		4500											396			279	774
Right Wall = 0.45m^2			3	ineffective decon												no successful decon	
								54									50.4
								59.4									43.2
Back Wall = 0.63m^2			5	ineffective decon		8	1st successful decon cycle					10				2nd successful	
								54									36
								23.4									45
								36									25.2
		430															
		450						50.4									25.2
		14															
	15	135															
	200	60		70			50				19.8		11.7			6.3	
Left Wall = 0.45m^2			2	ineffective decon		4										1st successful	
	160			160			100	108		9	54					20.7	50.4
total decon time (min)			13			21			5			18			5		
drying time (min)			40									30			1080		
survey time (min)				10			25			10			3			25	
Averages (cpm/cm2)	**Intital Conditions**			**Ineffective Decon**						**1st Successful Cycle**						**2nd Successful Cycle**	
Left Wall = 0.45m^2			2			4											
	160									20.7							
Back Wall = 0.62m^2			5			8						10					
	107.5	217.8								50	36.72					6.3	32.85
Right Wall = 0.45m^2			3									5					
Floor = 0.62m^2			3			9						3					
	174	598								44	83					8	23
Front Wall = 0.16m^2												5					
	1170	4500								169.2	774						
Averages (dpm/100cm2)																	
Left Wall = 0.45m^2			2			4						5					
	32,000									4,140							
Back Wall = 0.62m^2			5			8						10					
	21,500	43,560								10,000	7,344					1,260	6,570
Right Wall = 0.45m^2			3									5					
Floor = 0.62m^2			3			9						3					
	34,700	119,650								8,750	16,560					1,500	4,644
Front Wall = 0.16m^2												5					
	234,000	900,000								33,840	154,800						
avg (dpm/100cm2)	80,550	354,403								14,183	59,568					1,380	5,607
DF										5.7	5.9					10.3	10.6