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Conversion of Transuranic Waste to Low Level Waste by Decontamination—A Technical and Economic Evaluation

R. P. Allen
R. F. Hazelton

December 1984

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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CONVERSION OF TRANSURANIC WASTE TO LOW LEVEL WASTE BY DECONTAMINATION - A TECHNICAL AND ECONOMIC EVALUATION

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Richland, Washington 99352

SUMMARY

A study was conducted to evaluate the technical and economic feasibility of using in-situ decontamination techniques to convert glove boxes and other large TRU-contaminated components directly into LLW. The results of the technical evaluation indicate that in-situ decontamination of these types of components to non-TRU levels is technically feasible. Applicable decontamination techniques include electropolishing, hand scrubbing, chemical washes/sprays, strippable coatings and Freon® spray-cleaning. The removal of contamination from crevices and other holdup areas remains a problem, but may be solved through further advances in decontamination technology. Also, the increase in the allowable maximum TRU level from 10 nCi/g to 100 nCi/g as defined in DOE Order 5820.2 reduces the removal requirement and facilitates measurement of the remaining quantities.

The major emphasis of the study was on a cost/benefit evaluation that included a review and update of previous analyses and evaluations of TRU-waste volume reduction and conversion options (Brown 1982; Allen 1982). The results of the economic evaluation show, for the assumptions used, that there is a definite cost incentive to size reduce large components, and that decontamination of sectioned material has become cost competitive with the size reduction options. In-situ decontamination appears to be the lowest cost option when based on routine-type operations conducted by well-trained and properly equipped personnel.

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INTRODUCTION

One direct means of reducing the cost and potential handling and transportation hazards associated with the management and ultimate disposal of transuranic (TRU) waste is to reduce the amount and TRU content of this waste. Substantial work is in progress to develop and field demonstrate advanced assay instrumentation to facilitate the identification and segregation of low level waste (LLW). The Transuranic Waste Management Systems Office, through its Reduction in Waste Arisings program activities, has identified four other areas that offer significant opportunity for further reduction in the volume and TRU content of defense related TRU waste streams. These are:

- Administrative control - This includes control of types and quantities of material introduced into process areas, information exchanges and awareness training programs, and review/preparation of flow sheets for methods to reduce the production of waste materials.
- Materials substitution - This includes the design, treatment or coating of equipment, tools and materials to extend usefulness and lifespan or to provide longer-lasting or ease-of-decontamination qualities.
- Process development or optimization - This includes the improvement of current processes or the development of replacement processes to effect a reduction in waste for common operations such as materials dissolution, ion exchange, solvent extraction and precipitation.
- New equipment utilization - This includes the use of new equipment, such as bagless posting systems, to effect a reduction in the waste from process or production operations.

As part of the Administrative Control program activities, a study was conducted at Pacific Northwest Laboratory (PNL)[(a)] to provide analytical data for ways in which newly generated defense waste can be changed from the TRU waste category into the LLW category by decontamination. This study included a review and update of previous analyses and evaluations of volume reduction and conversion options (Brown 1982; Allen 1982). Major emphasis, however, was on a technical feasibility and cost/benefit evaluation of the use of in-situ decontamination techniques to convert glove boxes and other large TRU-contaminated components directly into LLW.

An earlier study conducted at PNL (Allen 1982) demonstrated that the size reduction of glove boxes and similar large TRU-contaminated components can provide substantial savings in packaging, storage, retrieval, transportation and WIPP-disposal costs for Hanford waste. Although decontamination of sectioned waste to non-TRU levels was included as part of this study, this approach was not the lowest-cost treatment option because of the relatively high cost of sectioning material into the small size (about 20 x 20 cm) required for optimum processing by vibratory finishing (McCoy, Arrowsmith and Allen 1980).

One way of reducing decontamination costs is to eliminate the sectioning operation by using in-situ decontamination techniques to convert components directly into non-TRU waste. This approach has not been used extensively in the past, primarily because of the difficulty of adequately decontaminating and monitoring crevice, gasket seal, and other potential contamination holdup areas.

Two recent developments now warrant a reconsideration of this direct conversion approach. One is the ten-fold increase in the levels defining TRU waste to greater than 100 nCi/g as specified in DOE Order 5820.2. This change should substantially reduce the extent and cost of decontamination required and also help alleviate the component monitoring problem.

[(a)] Operated by Battelle Memorial Institute.

The second development is the availability of new and potentially more effective in-situ decontamination techniques. Previous studies (Allen 1979a) have shown that in-situ electropolishing, for example, can reduce plutonium-contaminated metallic glove box surfaces from levels greater than 1000 nCi/g to less than 1 nCi/g. In addition to this electropolishing technique, work by commercial firms (Fowler 1982) has demonstrated that high-pressure Freon spray cleaning is very effective in removing smearable fission product contamination from a variety of metallic and nonmetallic surfaces. Recent progress also has been made in developing and using strippable coatings for decontamination applications, including a "self-stripping" formulation.

This report is divided into two major sections. The first section addresses the technical feasibility of converting TRU waste directly into the LLW category using in-situ decontamination techniques. It includes an overview of demonstrated and potentially applicable techniques, a description of experimental studies conducted to evaluate the Freon spray cleaning and self-strip coating techniques for TRU waste conversion applications, and a consideration of the monitoring requirements and available technology for verifying the in-situ decontamination of components to levels permitting disposal as LLW.

The second major section of the report focuses on the economic feasibility of the direct conversion approach and includes cost/benefit evaluations and comparisons with other current and projected TRU waste handling, processing and disposal options.

TECHNICAL EVALUATION

The removal of TRU contamination from the interior of glove boxes or other contaminated component surfaces requires a decontamination technique or combination of techniques that is applicable to a variety of base materials (metal, rubber, plastic, glass); surface materials (paint, corrosion layers, oil, grease, dirt, tape) and surface conditions (rough, polished, porous, impermeable). The contamination requiring removal may be on the surface; associated with or incorporated in surface materials; diffused or abraded into the base material; occluded within or under crevices, fissures and gasket seals; or contained within equipment or other potential holdup areas.

In addition to addressing these general decontamination application and effectiveness requirements, an in-situ decontamination technique must be sufficiently adaptable to be used inside sealed systems representing a variety of sizes and geometries under what may be relatively poor visibility and accessibility conditions. Other important considerations in the selection and application of in-situ decontamination techniques include secondary waste volumes and form, processing rates, personnel exposure, operating and capital costs, and industrial safety.

The following section provides an overview of some of the techniques that either have been or potentially could be used for the in-situ decontamination of glove boxes and other TRU-contaminated components. It is followed by a more detailed discussion of the Freon spray cleaning and strippable coating techniques, including the experimental evaluations conducted as part of this study. The final section addresses the problem of monitoring the decontaminated components to verify conversion to non-TRU levels, recognizing that most of the remaining contamination may reside in relatively inaccessible areas.

TECHNIQUE OVERVIEW

Regardless of the decontamination techniques used, there are certain preparatory operations that are required to place the glove box or other components in a safe condition for the decontamination operations and to remove potential sources of recontamination. These operations include:

- Examination of exterior surfaces for contamination and removal of dirt and debris.
- Inspection of the component for containment integrity and replacement of gloves, bags and other items as required to restore the component to an operational condition.
- Replacement of the HEPA filters to remove a major source of recontamination.
- Disassembly and removal of internal equipment and other items to the extent practicable.
- Removal of gross contamination using manual or other suitable techniques.

It may be necessary in some cases to adapt or employ special equipment to facilitate the decontamination operations. At the Savannah River Plant, for example, a fiber optics system with a video camera and recorder is used to help plan and guide decontamination operations inside glove boxes with poor visibility due to radiation-induced deterioration of the panels.

After completion of the decontamination work and final monitoring, fixatives may be applied to immobilize any remaining contamination, followed by removal of filters and sealing of glove and bag ports in preparation for component disposal as LLW.

Hand Scrubbing

Hand scrubbing and related manual-type decontamination operations such as vacuuming are commonly used to remove gross contamination to prepare glove boxes and other TRU-contaminated components for storage or as a first step in a more thorough decontamination effort. The contaminated surfaces are wiped or scrubbed, by hand or with a power brush, using cleaning/scouring materials and chemical cleaning agents suited to the nature of the surface and the decontamination requirements; e.g., contamination on the plastic panels, embedded in the metal floor, or associated with corrosion layers. Organic solvents and detergents can be employed to remove contamination associated with oil, grease and various types of surface soil. Removal of contamination from crevices and constricted areas can be enhanced by using foaming-type cleaners.

Although hand scrubbing is labor intensive, it can be cost effective and generate minimal secondary waste if properly employed by knowledgeable and well-trained personnel. However, radiation exposure may be a concern for some in-situ decontamination applications.

Chemical Washes/Sprays

Aggressive chemicals applied as washes or sprays have been used both as a pretreatment and to decontaminate glove boxes in place. At the Savannah River Plant, an oxalic acid application supplemented by hand swabbing is used to remove rust and sludge from glove box floors as a precursor to other decontamination operations. Previous studies at the Savannah River Laboratory (Crawford 1978) demonstrated that stainless steel can be decontaminated to non-TRU levels using a two-step process that employs alkaline permanganate to extract chromium from the protective oxide film on the stainless steel, followed by the application of oxalic acid to complete the removal of the modified film. This approach has been further modified (Wobser 1983) by substituting acidic permanganate for the alkaline permanganate, and by increasing contact temperatures and times. The current procedure is to apply the decontamination solutions as a recirculating spray at 60°C to the inside of the glove boxes. A 4-wash cycle removes 1-3 mils of stainless steel glove box surface, with the highest removal rate occurring on the glove box floor due to the longer contact time with the solution.

The use of inorganic acids to decontaminate glove boxes without disassembly also was investigated at Los Alamos National Laboratory (Garde, Cox and Valentine 1982). The inside surfaces of 20 representative plutonium-contaminated glove boxes from the DP West Plutonium Facility were spray washed using a 20% HNO_3 - 3% HF decontamination solution. One wash-rinse cycle removed about 85% of the plutonium inventory. Although the studies indicated that the residual contamination could be reduced to non-TRU levels by repeated wash cycles, the decontamination project funding and schedule would not permit use of this approach for the remainder of the glove boxes.

In-Situ Electropolishing

Although electropolishing is usually used to decontaminate metallic materials in an immersion mode, it can be applied as an in-situ technique to decontaminate the interior metallic surfaces of glove boxes, pipes, tanks, ducting and other representative TRU-contaminated components. As noted previously, tests conducted at PNL (Allen 1979a) have shown that in-situ electropolishing can readily remove contamination from the heavily used, highly contaminated floor of a plutonium glove box. The levels were reduced from 1100 nCi/g to 0.2 nCi/g for the 0.45-cm-thick stainless steel plate. For comparison, decontamination efforts using conventional scrubbing techniques with cleaners could not reduce the levels below about 500 nCi/g. The use of in-situ electropolishing techniques to rapidly and effectively decontaminate the inside of pipes and tanks also has been demonstrated.

The major disadvantage of electropolishing for the in-situ conversion of TRU-waste to LLW is its inapplicability to nonmetallics. In the case of a glove box, for example, electropolishing would have to be used in conjunction with hand scrubbing or another suitable method for the panels and other nonmetallic components. Although electropolishing exhibits good throwing power, or the ability to clean inside crevices (Allen et al. 1978), the complete removal of contamination from holdup areas also would be a problem.

HIGH-PRESSURE FREON CLEANING

Systems have been developed that use commercial Freon cleaning solvents applied at pressures up to 21,000 kPa to remove smearable contamination from a variety of items and surfaces (Fowler 1982). These systems operate in a recirculation mode to recover, purify (by filtration or distillation) and reuse the Freon. The only secondary waste generated is the surface material removed by the solvent. Other advantages of the Freon spray over comparable-pressure aqueous spray systems include removal of contamination associated with grease, oil and other Freon-soluble substances; ability to clean electrical parts and other equipment without damage to delicate components; a low viscosity and surface tension that facilitate penetration into crevices and other constricted areas; and applicability to a variety of materials including metals, rubber, cloth and plastic.

Although high-pressure Freon cleaning technology has been successfully applied to a variety of power reactor decontamination tasks involving the removal of smearable fission-product contamination, no studies have been conducted to evaluate its effectiveness for the removal of plutonium and other transuranics. In particular, its use for the in-situ decontamination of glove boxes and the potential of utilizing the unique solvent and penetration characteristics of the Freon for cleaning contamination holdup areas has never been investigated. A study was therefore undertaken to evaluate the technical feasibility of using Freon cleaning for the in-situ decontamination and direct conversion of plutonium-contaminated glove boxes to non-TRU waste under the revised definition of TRU waste in DOE Order 5820.2.

The Freon decontamination tests were conducted using a commercial Freon spray cleaning system consisting of a high-pressure pump capable of supplying Freon at a pressure of 14,000 kPa and a flow rate of 8.0 L/min; a reservoir, filter and low-pressure pump that continuously circulated the Freon through the filter; and a vacuum return system to collect and recycle the Freon. The vacuum pickup line and the high-pressure hose were introduced into a representative plutonium-contaminated glove box through one of the glove ports. The glove box was angled so that the Freon would run to one corner for collection. The glove box also was attached to the building filtered exhaust system with the Freon system exhausting into the glove box to maintain the necessary pressure differential for contamination control.

Two different types of nozzles and nozzle assemblies were evaluated in these initial studies. One was a spray head employing either a single pencil jet or fan jet. This was used with the inlet to the vacuum collection system located at the low point of the glove box. The second type of spray system had three fan jets mounted in a linear array with the vacuum return surrounding the jets (as in a vacuum cleaner) for immediate collection and return of the Freon.

The experimental parameters investigated in addition to nozzle type were pressure, type of surface (stainless steel floor versus Plexiglas® walls) and Freon purity. Decontamination effectiveness was evaluated by taking smear samples from approximate 100 cm^2 areas. Selected areas were cleaned using conventional hand scrubbing techniques for comparison with the Freon jetting tests.

The results of these studies are summarized in Table 1, and indicate that the decontamination effectiveness for plutonium is less than would be expected based on the good results obtained for fission product contamination. Discounting the variations inherent in smear readings, there was no consistent variation in effectiveness with pressure, nozzle type or surface material. The best results were obtained with hand scrubbing, and cleaning with a commercial cleaner was substantially more effective than scrubbing with Freon.

Based on discussions with the manufacturer, system and procedural modifications were made and additional tests performed to improve decontamination performance. Alcohol was added to the Freon to further reduce the surface tension and enhance wetting. New nozzles were provided to permit system operation at full pressure and flow conditions. The Freon system, nozzle and glove box were grounded to eliminate possible electrostatic particulate-adhesion problems. The initial tests were conducted with a 1 μm filter in the Freon system. This was changed to an 0.2 μm absolute filter (which subsequently proved defective). The recontamination potential of the filtered Freon was evaluated by spraying clean stainless steel coupons. The resulting smears for a 100 cm^2 area were 20,000 dpm and the corresponding direct reading was 200,000 dpm. These values show that recontamination by the recycled Freon was not the cause of the poor decontamination performance, and also illustrate the usually observed fact that the smearable contamination is some fraction of the fixed contamination. As a further check on recontamination, some of the tests were conducted using once-through Freon.

®Plexiglas is a registered trade name of Rhom and Hass Co., Independence Mall West, Philadelphia, PA.

TABLE 1. Effect of Nozzle Type, Pressure and Location on Smearable Contamination Levels and Decontamination Factors for Freon Spray Cleaning of Plutonium-Contaminated Glove Box Areas

Nozzle Type/Technique	Pressure (kPa)	Location	Before (dpm)	After (dpm)	Decontamination Factor
Single-Head Fan	700	Floor	1×10^6	1×10^6	1
Single-Head Fan	700	Wall	2×10^6	3×10^5	7
Pencil Jet	1,000	Floor	1×10^7	4×10^6	3
Pencil Jet	1,000	Wall	6×10^4	8×10^4	--
Pencil Jet	3,400	Floor	4×10^6	2×10^6	2
Single-Head Fan	14,000	Floor	2×10^6	2×10^5	10
Triple-Head Fan	14,000	Floor	7×10^6	3×10^5	23
Triple-Head Fan	14,000	Wall	2×10^6	2×10^6	1
Hand Scrub Using Clean Freon	--	Floor	4×10^6	2×10^5	20
Hand Scrub Plus Freon Fan Spray	--	Floor	8×10^6	4×10^5	20
Hand Scrub Using Commercial Cleaner	--	Floor	8×10^6	4×10^4	200

The results of these additional tests are given in Table 2, and show that there is no obvious beneficial effect of grounding, once-through Freon, or full-pressure (14,000 kPa) operation with an optimum 15° fan jet nozzle. The only consistent variation noted was the removal of more contamination from the initially more highly contaminated floor area as compared with the wall areas. Overall, however, the average decontamination factor for the removal of smearable plutonium contamination from the glove box stainless steel and Plexiglas surfaces remained less than 10.

The evaluation of in-situ Freon cleaning techniques was completed with a final series of tests that included use of a fixture to maintain exact nozzle spacing and angle while spraying test coupons, the cleaning of representative surface areas inside a walk-in glove box using the three-jet spray head, and tests on materials sprayed while inside a rotating basket to simulate the processing of sectioned material. All of the test results confirmed the earlier work in showing incomplete removal of the smearable contamination and only modest decontamination factors. These latter tests also were designed to investigate the effectiveness of the Freon spray in removing plutonium contamination from representative holdup areas, such as the groove in a glove box window gasket, the intersection of a wall and floor, threads protected by a nut, and a 0.64-cm-deep crevice between two stainless steel plates. The Freon readily penetrated the holdup areas and removed contamination, but only sufficiently to give decontamination factors of 2-20. Freon losses by evaporation were very high, resulting in redeposition of the contamination removed from the crevice areas.

A comparison and evaluation of the various Freon cleaning tests conducted on plutonium-contaminated surfaces suggests, as expected, that there is little effect on the fixed surface contamination. Since removal of the fixed contamination requires erosion of the base material, this is a possibility only for some nonmetallic materials and coatings. Higher pressures and operation in a cavitation or droplet erosion mode might be explored as a means of removing some of the fixed contamination from a wider range of surfaces.

TABLE 2. Effect of System Grounding and Recirculated Versus One-Pass Freon on Smearable Contamination Levels for Freon Spray Cleaning of Plutonium-Contaminated Glove Box Areas Using a 15° Fan Nozzle at 2000 psi With 6% Alcohol in the Freon

Location	Grounded	Once-Through	Before (dpm)	After (dpm)	Decontamination Factor
Floor	Yes	Yes	4×10^5	2×10^4	20
Floor	Yes	Yes	2×10^5	1×10^5	2
Wall	Yes	Yes	3×10^4	3×10^4	1
Wall	Yes	Yes	3×10^4	2×10^4	2
Floor	Yes	No	3×10^5	5×10^4	6
Wall	Yes	No	3×10^4	7×10^3	4
Wall	Yes	No	7×10^4	3×10^4	2
Wall	No	Yes	4×10^4	2×10^4	2
Wall	No	Yes	4×10^4	1×10^4	4
Floor	No	No	5×10^5	3×10^4	17
Floor	No	No	1×10^5	2×10^4	5
Wall	No	No	3×10^5	4×10^4	8
Wall	No	No	4×10^4	7×10^3	6

With respect to the smearable plutonium contamination, effective decontamination requires dislodgement, transport and collection of small, insoluble oxide particles. The coupon studies provide a good test of the dislodgement capability of the Freon spray, since the contamination only requires transport to the edge of the coupon to effect removal from the measurement area. The relatively low smearable values obtained for the coupons and an apparent insensitivity to experimental parameters would suggest that dislodgement is adequate even for the lowest pressures and flows.

The relatively poor decontamination results for actual glove box applications and the comparatively better results obtained with even hand scrubbing would suggest that the transport step is a problem for Freon decontamination, as for any fluid/insoluble particle combination. The dispersion and rapid evaporation of the Freon under spray conditions (except when used with a vacuum head attachment) certainly contribute to this particle transport problem. It might be possible to optimize Freon for removal of particulate contamination by operating at pressures just adequate to dislodge the particles, but at substantially higher flows to enhance particle transport.

The Freon spray does have the ability to penetrate and clean contamination holdup areas; however, the dispersion and redeposition of the contamination remains a problem.

In summary, the test results indicate that Freon spray techniques are moderately effective in removing smearable plutonium contamination, and may be useful in extracting contamination from holdup areas. The use of present Freon techniques would not appear to offer a significant advantage over more conventional methods except where criticality safety, component damage or secondary waste concerns would justify the development of a system engineered specifically for plutonium service. However, some recent tests have been conducted by Freon system manufacturers that indicate the possibility of adding complexing agents to the Freon to enhance the contamination collection and transport properties for actinides. If successful, this approach could substantially increase the effectiveness of the high-pressure Freon spray technology for direct-conversion in-situ decontamination applications.

STRIPPABLE COATINGS

A number of film-forming, synthetic polymer formulations have been developed that can be applied as a liquid to surfaces to immobilize and incorporate smearable contamination. After curing, the solid film and entrained contamination can be removed by stripping. The coatings are generally applied as a spray using an airless sprayer, although slower brush, squeege and roller methods can be used. If required, the film can be worked into the surface using a scouring pad. Maintaining the required coating thickness to permit ready stripping after curing is essential, as labor costs and exposure can be substantially higher if the coating must be removed by scraping. Even with proper application, stripping can be difficult for rough or porous surfaces.

Strippable coatings have been used both at the Savannah River Plant and at Hanford to remove gross contamination from the inside of glove boxes. At Hanford, more than 50 g of an estimated 70 g of residual plutonium were removed by four applications of a strippable coating to a process glove box. However, spray application is important to minimize personnel exposure when working with large residual inventories. The SRP work indicates that the brush application of coatings requires more than four times as long as the spray method.

The time and exposure required to remove the coatings may be further reduced by the recent development of a self-stripping coating. This formulation was originally developed as a rust remover (Barabas 1984), but shows promise for decontamination applications. When applied to a rusty surface, the polymer penetrates and bonds to the corrosion layer. Upon curing, the polymer contracts and develops sufficient internal stress to spall the corrosion layer from the substrate. After spalling, the coating can be collected by vacuuming. The coating also is water soluble, even after curing, and can be removed by scrubbing for areas that fail to spall.

Tests of this self-stripping coating at SRL on a representative plutonium-contaminated hood gave decontamination factors for smearable contamination ranging from 20 to 600. The application time was 10 min, with 20 min required to collect the resulting contaminated flakes.

Additional studies were conducted at PNL to investigate the effectiveness of this coating for reductions in total contamination levels (fixed plus smearable) and to compare the levels after self-spalling with final contamination levels after other removal options. The results are summarized in Table 3.

For the contaminated, corroded carbon steel, the self-stripping coating removed the rusty layer and the entrained contamination to give a decontamination factor of 2.5. The final smearable contamination level was only 7000 dpm/100 cm^2. Although the decontamination factors were less than 2 for the bare stainless steel surfaces, these samples had previously been decontaminated during the Freon tests. The smearable contamination levels were comparatively low, so the observed decontamination by the self-stripping coating reflects the removal of some of the more tightly adherent, or fixed contamination. The coating removal tests indicated no essential difference in decontamination effectiveness for coatings removed by self-stripping as compared with thinner coatings removed by wiping with a wet cloth. Some decontamination effect also was noted for coatings removed before curing as compared with direct wiping of the contaminated surface with a wet cloth.

As in the case of the Freon sprays, the self-stripping coatings cannot decontaminate to the levels achievable with aggressive chemicals or electropolishing. However, they should be useful in removing gross contamination and decontaminating some portions of the waste to non-TRU levels. The effectiveness of these coatings in removing contamination entrained in crevices and other holdup areas requires evaluation. Also, because of the water soluble nature of the cured coating, this decontamination method would facilitate recovery of transuranics.

POST-DECONTAMINATION MONITORING

Verifying the in-situ decontamination of a glove box or other component to non-TRU levels is potentially more difficult than the actual decontamination operation because of the inaccessibility of the residual contamination. The previously-referenced studies conducted at Los Alamos National Laboratory (Garde, Cox and Valentine 1982) indicated

TABLE 3. Effect of Surface Condition and Application Procedure on the Decontamination Effectiveness of Self-Stripping Coatings for Fixed and Smearable Plutonium Contamination

Specimen/Treatment	Direct Reading ($dpm/100\ cm^2$) Before	After	Decon. Factor
Rusty Carbon Steel/Self-Stripping	1.8×10^4	7.2×10^3	2.5
Bare Stainless Steel/Self-Stripping	8.1×10^3	4.1×10^3	2.0
Bare Stainless Steel/Self-Stripping	1.4×10^4	8.1×10^3	1.7
Bare Stainless Steel/Self-Stripping	1.4×10^4	8.1×10^3	1.7
Bare Stainless Steel/Self-Stripping	8.1×10^3	6.8×10^3	1.2
Bare Stainless Steel/Self-Stripping	1.9×10^4	1.4×10^4	1.4
Bare Stainless Steel/Self-Stripping	1.1×10^4	1.1×10^4	1.0
Bare Stainless Steel/Self-Stripping	1.4×10^4	8.1×10^3	1.7
Bare Stainless Steel/Self-Stripping	1.4×10^4	1.1×10^4	1.3
Bare Stainless Steel/Self-Stripping	2.2×10^4	1.6×10^4	1.4
Bare Stainless Steel/Self-Stripping	1.4×10^4	7.8×10^3	1.8
Bare Stainless Steel/Light Coat -	2.1×10^4	1.5×10^4	1.4
Removed After Curing Using a Wet Cloth	1.9×10^4	1.4×10^4	1.4
Bare Stainless Steel/Heavy Coat -	2.8×10^4	2.6×10^4	1.1
Removed Before Curing and Spalling	1.9×10^4	1.4×10^4	1.4
	1.9×10^4	1.1×10^4	1.7
Bare Stainless Steel/No Coating -	2.2×10^4	2.0×10^4	1.1
Wipe Surface With a Wet Cloth	1.7×10^4	1.5×10^4	1.1

that the actual plutonium content of decontaminated glove boxes was five times higher than the measured value due to contamination holdup in cracks, corners and other shielded locations.

This measurement problem has been partially alleviated by the increase in the levels defining TRU waste. There are four basic monitoring techniques that can be used to measure TRU content (primarily Pu-Am) inside glove boxes down to gram quantities in low background areas. These are described briefly in the following paragraphs and summarized in Table 4:

- Activated Disc Method - Metal discs are placed on the external surfaces of the component and activated by the neutrons from the internal contamination. The discs are then removed to a fixed, sensitive gamma counter where the slight induced radioactivity is measured. The amount of contaminant can be calculated from the derived value for the neutron flux. The major advantage of this method is that it can be used in the presence of high beta/gamma fields. Also, it is convenient for components with accessibility problems. However, the disc exposure time is 1-3 days, which would not be adequate to guide decontamination operations, but would be suitable for a post-decontamination measurement.

- Black Box Grid Technique - For Pu, this method uses the ~415 KeV Pu gammas (and neutrons if large quantities of Pu are involved) to quantitatively measure the Pu concentrations in specific sections of the glove box. These are then summed to give a total value. This approach was originally developed (Kindle 1976) to locate multigram quantities of holdup Pu in process glove boxes. However, when used by experienced personnel, it should be capable of measuring Pu contents to less than a gram per glove box in many situations. It is well suited to pinpointing the specific location of the residual contamination. The detector could be either NaI or a small Ge unit.

- Alpha-Gamma Method - This is the same as the previous technique, but with the addition of controlled geometry alpha measurements on the accessible interior surfaces.

TABLE 4. NDA Options for Determining Plutonium in Glove Boxes

	Activated Disc	Black Box Grid	Alpha-Gamma	Elephant Gun
Directionality (Ease of Locating Holdup)	Poor	Very Good	Very Good	Poor
Method Sensitivity	Excellent	Adequate	Adequate to Superb	Adequate
Time to Assay Glovebox	Days	Hour(s)	Hour(s)	Hour
Time to Determine Changes in Clean-Up Area of Glovebox	Days	Hour	Hour	Hour
Sensitivity to Errors in Assigning Matrix or Shielding Factors	Matrix-Extreme Shielding-Low	Matrix-Low Shielding-Moderate	Matrix-Low Shielding-Moderate	Matrix-Low Shielding-Moderate
Standards & Calibration Needed	None	Yes	Yes	Yes
Equipment Needed at Site	Discs Alone	Detector & Electronics (D+E); Shielded Holder (SH)	D+E; SH	D+E; SH; Rotating Platform + Crane, or Lots of Room
Relative Effect of Background Radiation	Difficult to Accommodate and Sensitivity Suffers Quite a Bit	Easy to Accommodate, but Sensitivity Suffers	Easy to Accommodate, but Sensitivity Suffers	Easy to Accommodate, but Sensitivity Suffers
Requires Entrance into Glovebox	No	No	Yes	No
Manhours to Initially Assay Glovebox	8-16	2-4	4-8	1[a]
Manhours to Monitor a Particular Location (Such as Post Cleanup)	8-16	1	1	1[a]

[a] Requires additional labor to isolate glove boxes from surrounding radiation sources.

- Elephant Gun Technique - This method uses gamma radiation to measure TRU quantities in the entire glove box or other component at one time. It requires either the ability to rotate the component in front of the detector, or sufficient space around the component so that the collimated detector can view the entire unit from a distance from both sides. A NaI detector can be used, but a Ge/GeLi detector would be better. This method would not identify the location of the holdup contamination.

The effect of the increase in TRU definition levels to greater than 100 nCi/g in verifying decontamination to non-TRU levels can be illustrated by a simple calculation. A representative 1.2 x 1.2 x 2.4 m glove box with metal frame and floor and Plexiglas top and sides would weigh more than 230 kg and have a maximum crevice and gasket region of 36 linear m. Assuming that the accessible interior surfaces could be decontaminated (and measured directly using an alpha probe) to less than 10 nCi/g, the amount of contamination that could be contained in the crevice and gasket regions with the glove box still remaining below 100 nCi/g would be more than 3×10^5 nCi/m of holdup region. This concentration of contamination could be readily detected using a collimated detector by comparison with adjacent cleaned areas. The detection requirements would be even less for glove boxes and components with higher weight-to-holdup area ratios.

For sites that are so equipped, a final verification of the TRU content of the decontaminated component could be made for appropriately sized components using the recently developed drum and crate assay systems (Caldwell et al. 1984). This measurement could be made on the packaged waste as a final step prior to transport to the LLW disposal site.

ECONOMIC EVALUATION

One of the major objectives of this study was to develop and correlate the economic data required to permit cost/benefit comparisons of the in-situ TRU waste conversion approach with other handling, processing and disposal options ranging from direct packaging of a glove box through size reduction, decontamination of sectioned material and/or treatment using major-site waste processing facilities. The following sections address the estimated costs for these various options and include a limited review and update of previous economic evaluations and related cost studies.

SIZE REDUCTION/DECONTAMINATION OPTIONS

TRU-contaminated glove boxes must be disposed of as TRU waste or be decontaminated to LLW when their service is no longer required. The objective of this portion of the study was to evaluate the economics of a few alternative handling and disposal methods involving size reduction and decontamination for representative, inactive Hanford Site glove boxes.

The TRU-contaminated components used as a basis in this study are two typical 1.2 x 1.2 x 2.4 m glove boxes and three conveyor sections having a total original waste volume of 8.92 m^3 and a total weight of 1510 kg. The original density of this waste is thus 170 kg/m^3. This is the same basis as used previously by Allen (1982). The disposal methods are compared by relative unit costs, i.e., $\$/m^3$ of original waste volume. For purposes of deriving relative unit costs a fixed original volume of 180 m^3 was assumed; this is the estimated amount of contact-handled, new, metal waste generated at the Hanford site as used by Brown (1982, p. 3-2).

Principal factors affecting handling and disposal costs are the extent of size reduction of the glove boxes, the approved, high integrity disposal container in which glove box parts would be placed, whether glove box parts would be decontaminated, and transportation.

It was assumed that the TRU waste containers would be shipped to the WIPP facility for disposal; LLW produced by decontamination would be disposed of at the Hanford site.

The elements examined for comparison of costs are:

- containers
- certification
- interim storage
- retrieval
- emplacement at WIPP
- size reduction
- decontamination
- LLW disposal
- railroad or truck transportation to WIPP

Alternative Methods for Glove Boxes

Five alternative methods other than in-situ decontamination for handling and processing glove boxes were evaluated and their unit costs are shown in Table 5. These are discussed below.

Case 1.

A single, high integrity disposal container having external dimensions of 2.8 m (L) x 1.7 m (W) x 1.8 m (H) is used for each intact glove box. The container cost is estimated to be $3300. No size reduction is performed but some miscellaneous handling costs are incurred. The lack of size reduction results in a waste packing density of about 100 kg/m^3 as opposed to the original of 170 kg/m^3. This results in a substantially higher total unit cost (see Table 5) as compared with the total cost of the other alternatives in which the packing density is increased.

After packaging of the TRU waste the containers are determined to be certifiable, and placed into interim storage. Later they are retrieved, overpacked as necessary, shipped to WIPP by railroad, and emplaced. Certification costs were derived from estimates of labor required to review glove box histories and prepare certification checksheets for each container of TRU waste to assure that it is certifiable. Storage and retrieval unit costs are those currently estimated for Hanford for certifiable TRU waste; the costs are, respectively, $913 and $1770 per m^3. The volume basis used by a long-established Hanford convention is the internal volume for drums (0.21 m^3/55-gal drum) and the external volume of other type containers. Railroad transportation

TABLE 5. Unit Costs, \$/m^3 of Original Waste Volume, to Manage and Dispose of Newly Generated, Contact-Handled, TRU-Contaminated, Glove Box Waste Shipped to WIPP by Rail

(1984 Dollars)

	Case 1	Case 2	Case 3a	Case 3b	Case 4
Containers	738	170	75	85	75
Certification	57	53	209	209	30
Storage	1,830	463	237	237	10
Retrieval	3,530	893	459	459	18
Railroad Transportation	2,810	777	712	900	36
TRUW Disposal (WIPP)	1,550	431	244	244	13
Size Reduction	46	388	2,080	2,080	--
Decontamination	--	--	--	--	2,450
LLW Disposal	--	--	--	--	47
TOTAL, Rounded	10,600	3,200	4,000	4,200	2,700

Case Description

Case 1. Little size reduction is used. Glove boxes are placed inside 2.8 m (L) x 1.7 m (W) x 1.8 m (H) containers which, in turn, are placed into TRUPACT bimodal shipping containers and transported by rail to WIPP for disposal.

Case 2. Glove boxes are size reduced so that the waste can be placed into 1.7 m (L) x 1.4 m (W) x 0.97 m (H) containers.

Case 3a. Glove boxes are size reduced so that the waste can be placed into 55-gallon drums for individual handling and shipment.

Case 3b. Same as Case 3a, but the drums are handled as a six-pack.

Case 4. The waste from Case 3 is further size reduced and decontaminated by vibratory finishing. More than 96% of the original waste volume is disposed of as LLW. The small amount of secondary TRU waste is solidified and packaged in drums for handling and disposal as in Case 3a.

cost estimates were derived from rail charge formulas and calculated shipment weights and distances (one way - 1510 miles). Included in the transportation cost are the costs for leasing TRUPACT systems, estimated to be \$800/day for 21 days each round trip. This daily lease cost rate is based on private ownership of the TRUPACT system including two casks and a railcar, a total cost of \$1.6 million, an annual fixed charge rate (FCR) of 25%, and 250 days/yr use for the system. If the TRUPACT system were government owned, the lease cost would be in the range of \$480-\$640/day assuming the same annual usage, and an FCR range of 15 to 20%. Approximate round trip times determined by Daling and Engel (1983) were used. An estimated unit cost of \$773/m^3 was used for WIPP operations. External volumes of the containers were used to derive WIPP disposal estimates. Size reduction operation costs are updates of those developed by Allen (1982); the size reduction costs used in all the cases evaluated exclude costs required for amortization (or capital recovery) and maintenance of facilities. These bases were also applied in each of the following cases.

Case 2.

The glove boxes are reduced in size so that the parts could be placed into 1.7 m (L) x 1.4 m (W) x 0.97 m (H) containers. The waste packing density for this case was estimated to be 350 kg/m^3. A container cost of \$820 each was used. This is based on data given by a manufacturer of DOE-approved waste disposal containers. Size reduction unit costs are updates of data given by Allen (1982).

Case 3a.

Glove boxes are size reduced by disassembly and sectioning (such as plasma arc cutting) to allow placement of the sectioned parts into 55-gal drums. The density of the waste is increased by sectioning to 660 kg/m^3. The cost of each drum is \$60. In this case the drums are handled singly for interim storage and shipment to WIPP using the TRUPACT system.

Case 3b.

This case is similar to Case 3a except that the 55-gal drums are placed into six-packs before being shipped. Handling of the drummed waste in this form is reflected by several of the cost elements. The cost for bracing was estimated to be currently $50 per 6-pack (based on costs given by Brown 1982). Depending on design specifications, bracing costs could be considerably larger.

Case 4.

Size reduction is used more extensively in this alternative than in Cases 1 and 2 but not much more than that of Cases 3a and 3b to prepare glove box parts for decontamination. Following size reduction, glove box parts are decontaminated using vibratory finishing (McCoy, Arrowsmith and Allen 1980). The decontaminated materials are placed into 55-gal drums and disposed as LLW at current (FY 1984) Hanford costs of $191/m^3. Secondary wastes are also disposed of in 55-gal drums as TRU waste. The density of the material disposed of as LLW was assumed to be 660 kg/m^3. The size reduction and decontamination unit cost was updated from that used by Allen (1982). This operating cost is based on experience gained using the PNL size reduction facility. Excluded from this cost, as they were in the other cases, are the capital amortization and maintenance costs for size reduction and decontamination facilities.

Comparison of Unit Cost Data - Railroad Transportation

The unit costs for each alternative are compared in Table 5. With exclusion of capital-related costs, the most cost effective alternative is Case 4 in which glove boxes are extensively size reduced and the parts decontaminated for LLW disposal. This total unit cost for Case 4 is $2700/m^3 of original glove box volume.

If the LLW were disposed of at a site 310 km distant from the generation location, transportation and disposal costs (using a generic disposal cost of $560/m^3 for LLW) would increase the Case 4 costs to $2800/m^3. However, even with these changes, Case 4 would be the most cost effective alternative.

Size reduction to some extent is required for each alternative except Case 1. (Some handling costs are included in this category for Case 1.) In this evaluation, Case 1 is the least cost effective ($10,600/m^3 of original glove box volume), primarily due to the low packing density. If glove boxes larger than the reference glove box were to be disposed of, some size reduction would be needed to allow placement of the waste into an approved, high integrity overpack container for TRU disposal. The unit costs of Cases 2, 3a, and 3b, respectively, $3200, 4000, and 4200/m^3, show the combined effects of size reduction and containerization methods.

The capital and maintenance costs for TRU waste size reduction and decontamination can be highly variable because of the possible location of the facilities and the wastes that would be processed. However, these costs/facilities will increase the unit costs for all but the first alternative. To provide an indication of the relative effect of these costs, some approximate costs have been generated from actual or predicted costs for facilities at the Rocky Flats Plant (RFP). The Advanced Size Reduction Facility cost about $9.6 million; the cost for an adjacent decontamination facility is estimated to be about $3.4 million. About 2300 m^3/yr of waste would be processed if the daily waste volume were equivalent to that of a typical RFP glove box and processing were performed 180 days/year. Cost details are in Appendix A. The total unit cost for each case except Case 1, which uses no size reduction would increase to the following:

Case	Total Unit Costs (Rounded), Includes Approximate Facility Capital & Maintenance Costs, \$/m^3
1	10,600
2	3,600
3a	4,500
3b	4,700
4	3,300

Case 4 would remain the most cost effective although the total unit cost for Case 2 would be only about 10% more.

If WIPP were to become immediately operational a large portion of the costs for waste storage and retrieval would be deleted, and with this deletion Case 2 would become the most cost effective rather than Case 4. The effect of deletion of storage and retrieval costs on the individual case totals of Table 5 is shown below:

Case	Total Cost (Rounded) Excluding Storage & Retrieval Costs, $\$/m^3$
1	5,200
2	1,800
3a	3,300
3b	3,500
4	2,700

If the DOE were to own the TRUPACT railcar system and the lease cost were $480/day rather than $800/day, the total cost for each case would decrease from that in Table 5 to that below:

Case	Total Cost, $\$/m^3$ (Rounded)
1	9,800
2	3,000
3a	3,800
3b	4,000
4	2,700

Although the total unit costs would decrease with DOE ownership of TRUPACT systems, the case rankings would remain unchanged from that of Table 5: Case 4 would be the most cost effective, closely followed by Case 2.

Comparison of Unit Cost Data - Truck Transportation

A major cost shown in Table 5 is for TRUPACT transportation by railroad. Transportation costs could be reduced significantly if the waste were shipped by truck rather than by railroad car. Although only one TRUPACT cask would be used for a truck shipment rather than two as by railroad, time for a round trip would be considerably reduced thus decreasing TRUPACT lease costs. The daily lease cost for a truck

TRUPACT system, consisting of the tractor and trailer and a single TRUPACT cask, is estimated to be $700/day, assuming private ownership, a capital cost of $700,000, an annual fixed capital rate (FCR) of 25%, and a use rate of 250 days/yr. Assuming government ownership rather than private of the truck TRUPACT system, the same annual usage, and an FCR range of 15 to 20%, the lease cost range would be $420 to $560/day/TRUPACT. Costs per unit for weight are also less for truck shipments. An example of the effect of using truck transportation is that of Case 3b for which the transportation cost would be reduced from $900/m^3 to $350/m^3 of original waste volume. Similar unit cost reductions would occur for the other cases involving extensive transportation.

The effect of shipping TRU waste by truck for each case is shown in Table 6. Although there is no re-ordering of the cases from highest to lowest unit cost, the difference between Cases 2 and 4 essentially disappears. If the TRU waste transportation distance were increased from that used, 938 km, to a generic value, about 1240 km, additional transportation costs of about $60/m^3 would be incurred for Case 2 giving a total cost of about $2800. This increase in costs would again make Case 4 the most cost effective of the alternatives, but only marginally.

The inclusion of approximate capital and maintenance costs for size reduction and decontamination facilities changes the total unit costs for Cases 2 and 4 from those in Table 6 to the following:

Case	Total Unit Costs (Rounded), Includes Capital & Maintenance Costs, \$/m^3
1	8,900
2	3,100
3a	4,000
3b	4,100
4	3,300

This inclusion of approximate capital and maintenance costs makes Case 2 the most cost effective of these alternatives, but only by about 10% as compared with Case 4.

TABLE 6. Unit Costs, $\$/m^3$ of Initial Waste Volume, for TRU Contaminated Glove Box Waste Shipped to WIPP by Truck

(1984 Dollars)

	Case 1	Case 2	Case 3a[a]	Case 3b	Case 4
Containers	738	170	75	85	75
Certification	57	53	209	209	30
Storage	1830	463	237	237	10
Retrieval	3530	893	459	459	18
Truck Transportation	1100	300	280	350	14
TRUW Disposal (WIPP)	1550	431	244	244	13
Size Reduction	46	388	2080	2080	--
Size Reduction & Decontamination	--	--	--	--	2450
LLW Disposal	--	--	--	--	47
TOTAL, Rounded	8900	2700	3600	3700	2700

(a) Cases described in Table 5 footnotes.

If WIPP were to become immediately operational, a large portion of the costs for waste storage and retrieval would be deleted from the totals for each case given in Table 6. By this deletion, Case 2 would become the most cost effective of the cases considered. The effect is shown below:

Case	Total Cost (Rounded) Excluding Storage & Retrieval Costs, $/m^3$
1	3,500
2	1,300
3a	2,900
3b	2,900
4	2,600

Comparison With Previous Studies

One objective of this work was to compare these updated results for volume reduction of metal wastes with those of Brown (1982). In comparing the information from the two sources a few important differences were found. In the present work it is assumed that the metal waste form is glove boxes, which would have an initial density of 170 kg/m^3. Brown defined unprocessed metal waste only as metals, giving no configurations; he further gave a density of 420 kg/m^3 (Table 6, pp. 3-6) including the 1.2 x 1.2 x 2.1 m RFP box in which the waste is placed for interim storage. Values for volume reduction used in the Brown study assume newly generated waste had an approximately 2 to 1 reduction in packing for storage or shipment to storage. This implies careful packing or prior size reduction by part disassembly and a cutting operation, as does the use of the RFP box. It also suggests that the metal waste forms were relatively small as compared with a 8.92 m^3 glove box used in this study.

If Brown's newly generated metal waste had been disassembled or size reduced before placing it in the RFP box for interim storage, the associated cost for doing this work does not appear in the report. A controlled-environment size reduction facility of some type would be needed for these operations. It is noted that Brown examined both waste that was already in storage and waste that was newly generated.

Another difference between this work and that of Brown is the sequence of operations in the size reduction cases. Brown shows that size reduction to further reduce volume takes place following waste storage and retrieval. In this study, size reduction occurs before interim storage, and thus decreases the volume of material stored and the costs of storage and retrieval which are charged on a volume basis.

Brown indicates that with metal decontamination about 85% of the original metal waste volume (70% of original waste mass) can be removed from the TRU waste category. As pointed out previously, the initial configuration of this metal waste is undefined. In this study evaluating processing of glove boxes, about 96% of the original waste volume is removed from the TRU waste category.

In Brown's study the costs of containers (the RFP box), certification before interim storage, interim storage, and retrieval are not shown. These are probably assumed to be identical for each case, and since Brown's study only concerned volume reduction techniques and costs and waste disposal and transportation savings, these costs were not included. This is due to the use of volume reduction processes following waste retrieval instead of before.

In this work size reduction is done before final packaging and interim storage and it affects each individual cost because less volume of material is handled after size reduction than would have been handled without it. Table 5 reveals these effects.

Because of the apparent differences in waste forms and the sequence of operations, results from the two studies cannot be rigorously compared. The costs developed by Brown include capital and facility maintenance costs whereas those of this study do not. The costs generated in each study are shown in Table 7 for newly generated waste.

The data from Brown (1982) indicate that savings do not offset process costs, thus implying that no cost advantage is obtained by size reduction or by size reduction coupled with decontamination.

The data from this study show that size reduction coupled with decontamination (Case 4) gives a significant cost advantage over the

TABLE 7. Volume Reduction Costs for Newly Generated Metal Waste (Brown 1982) and for Glove Boxes (This Study)

Modified Data of Brown (1982) (Table 13, pp. 4-2, of Brown)

Process	\$/m³ of Newly Generated Waste[a] (1984 Dollars) Process Cost	Disposal & Transportation Savings
Size reduction	2300	570
Metal decontamination (includes size reduction)	3500	1000

Data of This Study (From Tables 5 and 6)

Overall Costs, \$/m³ of Original Glove Box Volume[b] (1984 Dollars)

	Case 1 - No Size Reduction of Glove Boxes - Handled Directly	Case 2 - Glove Boxes Size Reduced for 1.7 x 1.4 x 0.97 m Container	Case 3b - Glove Boxes Size Reduced for 55 gal Drums	Case 4 - Glove Boxes Size Reduced & Parts Decontaminated
Railroad Shipment	10,600	3,200	4,200	2,700
Truck Shipment	8,900	2,700	3,700	2,700

(a) Costs updated from Brown's 1981 costs using a labor inflation factor of 1.22. Capital and facility maintenance estimate costs included.

(b) Excludes capital and facility maintenance costs.

case in which no size reduction is performed (Case 1) and a comparatively modest cost advantage over cases in which no decontamination is conducted (Cases 2 and 3b). These data also show that there is no cost advantage to size reduce the waste beyond that which will fit into a 1.7 x 1.4 x 0.97 m container if decontamination were not to be performed (Case 2 vs. Case 3b). Furthermore, the data show only a marginal cost advantage for decontamination (Case 4) over partial size reduction (Case 2) if the TRU waste were shipped to WIPP by truck rather than by railroad. This margin may disappear with inclusion of capital and maintenance costs for a decontamination facility, if public benefits of decreasing the volume of TRU wastes shipped for disposal are not considered.

The conclusions reached in this study, showing cost advantages of size reduction and other processing of newly generated waste over that of no action, differ from those of the Brown study. This difference is probably due to a difference in the assumed form of the original waste, which in this study is glove boxes, and in the Brown study, an already size-reduced waste.

Inclusion of facility capital and maintenance costs would increase the unit costs ($\$/m^3$) for each case of this study except that of Case 1. Case 1 requires no facility for size reduction; the others do. Because the amount of size reduction required for Case 2 is less than that of Cases 3 and 4, its unit cost for capital and maintenance may be somewhat less than that of the other two. It is not expected that inclusion of this cost would change the overall order of costs for the cases.

COST ESTIMATES FOR PROCESSING FACILITIES

Other cost estimates have been prepared or real costs gathered for four facilities that will process TRU wastes. These facilities are or may be located at the Hanford site, the Idaho National Engineering Laboratory (INEL), and at the Rocky Flats Plant near Golden, Colorado.

The overall processing costs for the proposed WRAP (Waste Receiving and Processing) facility at Hanford to prepare TRU waste for shipping to WIPP are estimated to total $\$5300/m^3$ of original waste volume. This includes capital and maintenance costs and is based on the estimated total lifetime throughput for the facility, an estimated capital cost of $30 million, and an estimated lifetime operating cost of $60 million. The WRAP facility will handle all types of TRU wastes.

Two pilot plants are currently being developed, designed, and constructed at INEL to demonstrate methods for retrieving, processing, and/or certifying TRU waste for shipment and disposal demonstrations at WIPP (Tait 1984). The first facility at INEL is the Stored Waste Examination Pilot Plant (SWEPP) which is currently under construction. Its function is waste retrieval, nondestructive examination, certification, and the preparation of waste containers for shipment to WIPP. Non-certifiable waste is routed to the Process Experimental Pilot Plant (PREPP), the second facility. The primary objective of the PREPP is to experimentally demonstrate full-scale methods for processing uncertifiable INEL-stored waste into a form that conforms to WIPP acceptance criteria. The stored waste including its interim storage container will be size reduced by low speed shredding. PREPP is being designed and constructed for an estimated cost of about $21 million. The operating cost for PREPP has been estimated to be about $800-$1000 for producing a 55-gal drum of waste (113 kg/drum). The unit cost is about $8.80/kg, or about $4800/m^3 of packaged waste. This package volume unit cost can be compared only in general with a unit cost for original waste volume.

Mitchell, Aguilar, and Williams (1984) describe the Rocky Flats Advanced Size Reduction Facility (ASRF). The ASRF will be used to section 1.8 x 2.4 x 3.0 m glove boxes, and miscellaneous equipment to a size which can be easily handled and disposed of in a WIPP-approved waste container. The volume reduction target is two to one. The size of the planned, TRUPACT space efficient container is 0.97 m (H) x 1.37 m (W) x 1.73 m (L) having a usable space of 2.38 m^3. This is the same size as that used for Case 2 of this study. The capital cost for the ASRF is $9.6 million. No operating experience has yet been obtained. However, it has been estimated that a 14-man crew can process a glove box in an 8-hour shift at a labor cost equivalent to $330/m^3 of original glove box volume. This includes costs for placing the size reduced waste into the container but excludes container preparation and shipping.

It also excludes facility capital and maintenance costs. The ASRF labor cost for size reduction compares well with that of Case 2, which is $\$388/m^3$ (see Tables 5 and 6). The base operating cost for the older, existing Rocky Flats facility was about $\$640/m^3$ just to have personnel in the size reduction cell. Three 8-hour shifts using a crew of nine men each shift were required to process a glove box.

One thing clear from examining cost data from each of the sites and from this study is that direct comparisons cannot be made easily. This is because of site-specific criteria and the different processes that are used. Comparisons of the estimated cost for Case 1 of this study, in which no size reduction is performed, with estimated costs for Cases 2-4 and for WRAP, SWEPP and PREPP, and ASRF roughly show that size reduction of waste is economically advantageous. Case 4 of this study shows that size reduction followed by decontamination could give further advantages compared with Cases 1 through 3 if rail were to be the required mode of transportation. There is no significant economic difference between Cases 2 and 4 if transportation were to be by truck. If WIPP were to become immediately operational and all interim storage and retrieval costs could be deleted, Case 2 would be the most cost effective regardless of the method of transportation.

COST ESTIMATES FOR IN-SITU DECONTAMINATION

The cost data and estimates for the in-situ decontamination of glove boxes and other representative components to non-TRU levels are based on three sources of information: actual time/cost data from the preparation and manual decontamination of three large glove boxes; a review of previous in-situ decontamination operations using other techniques; and discussions with other site and contractor personnel conducting in-situ decontamination operations.

The glove box decontamination operations were conducted on three Hanford Site glove boxes contaminated with Cm, Am, Np, Eu, Cs, Sb, Co and Mn. The dimensions of the boxes were:

- 1.2 x 2.1 x 3.0 m ($7.9\ m^3$)
- 1.2 x 2.1 x 4.9 m ($12.7\ m^3$)
- 1.2 x 2.1 x 4.9 m ($12.7\ m^3$)

These glove boxes had been out of service for some time. The exterior surfaces were covered with dirt and debris and the inside contained an inventory of contaminated water in large tanks in addition to other equipment and miscellaneous trash. All of the glove and bag ports were sealed and the exhaust filters had been removed. It was necessary to return the glove boxes to temporary service, perform the decontamination, and then reseal and dispose of the boxes as LLW.

The following is a summary of the operations and the required labor:

Sequence of Operations

	Labor (Man-Days)
1. Examine the Exterior Glove Box Surfaces.	1

All exterior surfaces were checked for radioactive contamination. Plant health physics took smears and verified that exterior surfaces were not contaminated.

2. Clean the Exterior of Dirt and Debris.	2

The boxes were washed down with wet rags and household cleaners. This operation was performed before removing the covers on the glove and bag ports to provide a proper working environment and to facilitate decontamination if problems were encountered when the ports were opened and the gloves were changed.

3. Open the Glove Box, Removing Covers on Glove and Bag Ports. Examine Glove Ports and Gloves.	1

When the glove and bag ports were opened, each one was examined and tagged for changing.

4. Change Gloves and Bags.	3

Gloves and bags were changed as required before starting internal glove box operations. Approximately 24 pairs of gloves were changed in the three glove boxes.

		Labor (Man-Days)
5.	Install New Filters.	3
	The original HEPA filters were removed when the glove boxes were first taken out of service.	
6.	Take Internal Smears of Glove Boxes and Equipment.	5
	After reactivation of the glove boxes was complete, internal smears were taken to determine the location and extent of the contamination and permit comparison of the same areas through the decontamination operation.	
7.	Take Water Samples.	2
	Water samples were removed from inside the process equipment and analyzed for quantities and types of special nuclear materials.	
8.	Remove Accountable Materials and Equipment.	2
	All special nuclear materials were inventoried and removed from the glove boxes.	
9.	Identify Property Numbers for Property Control.	1
	Property control numbers were logged on any equipment located in the glove boxes and the proper property control documents were filled out and sent to management.	
10.	Disassemble and Removal All Equipment That Can be Removed.	25
	Equipment that could be disassembled (everything except a press and 4 tanks) was broken down into sizes and weights that could be safely removed through a 38-cm-diameter bag-out port. It should be noted that this operation was the most labor intensive part of the entire decontamination operation.	

	Labor (Man-Days)
11. Remove All Contaminated Water and Transfer for Disposal.	5

When all equipment was secured, the water (1400 L) was removed and transferred to a liquid waste disposal facility. The water tanks were then filled with absorbent to confine any remaining water.

12. Decontaminate the Glove Boxes.	7

The glove boxes were decontaminated using conventional hand scrubbing techniques and commercial cleaners. All surfaces were cleaned a total of three times.

13. Remove Glove Box Filters.	2

The HEPA filters were removed from the three glove boxes after it was determined that decontamination was complete. The three glove boxes were then washed down with rags and cleaner for a fourth time to remove any contamination from the filter removal operation.

14. Apply Fixatives to All Glove Box Surfaces.	7

Two coats of a polyvinyl alcohol fixative were applied to all glove box and equipment surfaces using pressure-pot spray paint equipment. When the fixative was dry, the interior glove box surfaces were smeared again using the same locations as originally mapped.

15. Seal All Glove and Bag Ports When Decontamination is Complete.	1

When decontamination was verified, the glove and bag ports were sealed and the boxes were ready to be removed as low level waste.

The total labor requirement for the 5-week operation was 67 man-days. The labor cost (at $50/man-hr) including planning, supervision and 5 man-weeks of monitoring coverage was $46,000. Additional costs included $5000 for protective clothing and supplies, and $14,000 for disposal of the resulting LLW and secondary TRU waste. The cost of packaging and transporting the decontaminated boxes as LLW is not included as similar charges would be incurred in operations involving handling components for storage or processing under the other treatment options. The total cost for the in-situ operations on the 33 m^3 of glove box volume was $65,000, or about $1900/$m^3$ of original volume. It should be noted, however, that some of the operations, such as water removal, were unique to these particular glove boxes. Wide variations in cost would be expected depending on the size and configuration of the glove boxes, the amount and type of contained equipment, the nature of the surfaces and holdup areas, the extent and type of decontamination employed, and other factors as discussed in earlier sections.

The cost of decontaminating the inside of a tank using in-situ electropolishing techniques was estimated based on the earlier development and demonstration of the procedure for a 1900 L radwaste tank (Allen 1979b). The work on the tank illustrated how the use of in-situ techniques can be used to decontaminate large surface areas and the ability to accomplish this remotely to reduce radiation exposure. The tank had been used for many years to collect primary coolant from a power reactor during maintenance operations and was contaminated with Cobalt-60 corrosion products. A variety of in-situ electropolishing techniques were used to reduce the internal radiation levels from 20 mR/h to background, with no residual smearable contamination. This was accomplished using only 210 L of electrolyte. Moreover, 85% of the interior tank surfaces were decontaminated remotely from outside the tank.

The tank was cylindrical, 7.3-m long and 1.8-m in diameter, and was made of 0.95-cm-thick stainless steel. Access of men and equipment was gained through a single manhole located on the top center of the tank. A perforated sparger line, about 10 cm in diameter and 7.3 m long, ran through the tank. The tank was decontaminated in-situ using a series of electropolishing devices. Electrolyte was supplied to these devices by a small pump mounted in the sump of the tank. The electrolyte flowed from the devices, was collected in the bottom of the tank, and then recirculated through the devices.

Most of the decontamination, 85%, was done using a large swab device that was magnetically coupled to an external holding and positioning fixture that permitted manipulation from outside the tank. Once the radiation level inside the tank was reduced, personnel entered and used a long, cane-shaped, pumped-stream device to decontaminate the corners and small, recessed areas.

The interior of the 7.3 m long sparger line was decontaminated by inserting and moving a perforated cathode equipped with a flexible seal at each end. The electrolyte was forced through the perforations in the cathode as in a pumped-stream device. The exterior of the sparger line was decontaminated using a swab device built to fit over the pipe. Small areas requiring additional decontamination were further treated using a small, hand-held swab device.

The decontamination cost for this tank, which included some developmental costs, was $20,000. Adding $5000 for LLW disposal costs and $10,000 for possible additional costs associated with a TRU operation gives about $1800/m^3 of original waste volume. However, experienced personnel using current-generation in-situ electropolishing devices and conducting routine decontamination operations should be capable of substantially reducing this cost except for tanks with difficult geometries, internal components or accessibility problems.

Discussions with other contractor and site personnel conducting in-situ decontamination operations disclosed another consideration that can significantly impact the cost of these operations. These are the administrative constraints imposed on the in-situ operations to ensure radiological and industrial safety. Because of the inherent "temporary" nature of in-situ work, these restrictions and requirements can result in significantly higher costs than projected for what otherwise would be relatively simple decontamination operations.

Another cost that must be considered as part of the in-situ evaluation is the expense of the post-decontamination monitoring work to verify conversion of the non-TRU category. These costs cannot be accurately projected until the procedures and technology have been fully developed and demonstrated. However, based on the labor estimates given in Table 4, the cost for experienced and properly equipped staff should be less than $180/m^3$.

DISCUSSION AND CONCLUSIONS

The technical evaluation suggests that in-situ decontamination of glove boxes and other components to non-TRU levels, particularly under the revised definition of TRU waste, is technically feasible. Electropolishing techniques have the demonstrated capability to reduce contamination levels on even corroded metallic surfaces to non-detectable levels. Hand scrubbing, chemical washes/sprays and strippable coatings potentially can clean accessible surfaces to the required levels, although multiple applications of a single technique or sequential applications of two or more of the techniques may be required.

The removal of contamination from crevices and other holdup areas remains a problem. However, the further development of the high-pressure Freon cleaning technology through optimization of pressure and flow or through the addition of complexing agents may provide a solution. As noted previously, the increase in the permitted residual TRU content means that significant and readily measurable quantities of contaminants can remain in the holdup areas if the accessible surfaces are adequately decontaminated.

The results of the economic evaluation as summarized in Figure 1 show that there is a definite cost incentive to size reduce large components, and that the decontamination of sectioned material has become more cost competitive with the size reduction option. In-situ decontamination appears to be the lowest cost option based on routine-type operations conducted with well trained and properly equipped personnel. However, a number of factors relating both to the unique nature of each decontamination project and externally-imposed constraints and requirements could alter this conclusion for particular sites or applications.

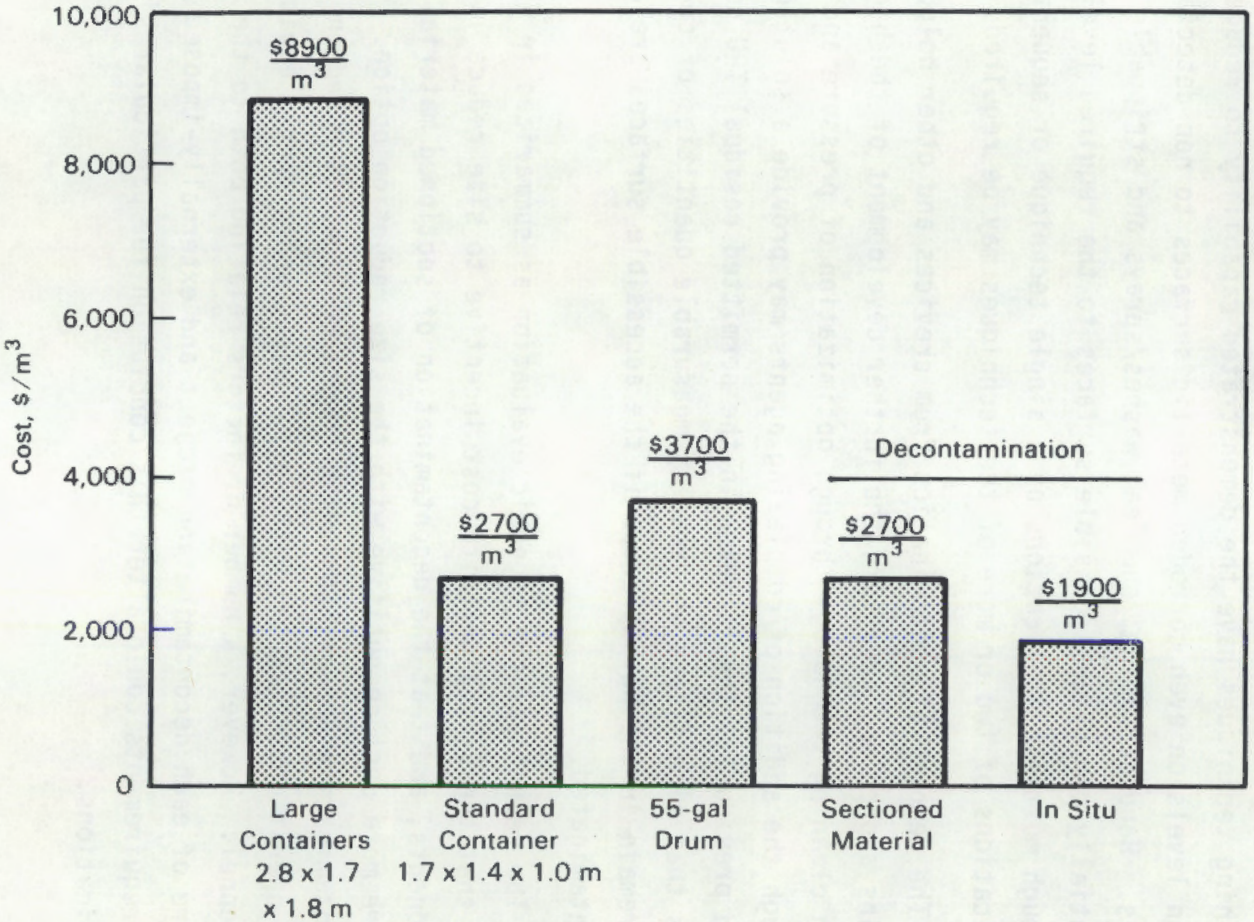

FIGURE 1. Total Unit Cost for TRUW Handling and Disposal Options, $/m³ of Original Glove Box Volume

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APPENDIX A

COST ESTIMATION DETAILS
FOR TREATMENT/DISPOSAL OPTIONS

APPENDIX A

COST ESTIMATION DETAILS FOR TREATMENT/DISPOSAL OPTIONS

Inactive glove boxes contaminated with transuranics (TRU) could be handled and processed in several ways, including size reduction by disassembly and sectioning methods such as plasma arc torch for ultimate disposal. Disposal would be either at WIPP if the material remained TRU waste or at a low level waste (LLW) site if it were decontaminated. Descriptions of processes considered are given in the Size Reduction/ Decontamination Options section along with unit cost comparisons. Cost estimation details are given here to show how the unit costs were obtained.

The cases examined to show the effects of size reduction by disassembly and sectioning and decontamination by vibratory finishing of the glove boxes are listed below:

Case 1. No size reduction or decontamination. Glove boxes are disposed of intact at WIPP in an overpack container 2.8 m long, 1.7 m wide, 1.8 m high.

Case 2. Size reduced to about one-half the initial volume. Glove box parts disposed of at WIPP in TRUPACT space efficient containers having dimensions of 1.7 m long, 1.4 m wide, 0.97 m high.

Case 3a. Size reduced to about one-quarter the initial volume. Glove box parts disposed of at WIPP in 55-gal drums handled singly.

Case 3b. Same as Case 3a, except that 55-gal drums are assembled into six-packs which are disposed of at WIPP.

Case 4. About the same size reduction as Case 3a. Glove box parts decontaminated by vibratory finishing and disposed of in 55-gal drums as LLW at the Hanford site. Secondary TRU-contaminated wastes placed into 55-gal drums and solidified. Drums grouped as six-packs and disposed of at WIPP.

CASE 1 DETAILS

Waste Form for Disposal

It is assumed for all cases that the waste form is that of two typical glove boxes and three conveyor sections, representing a total waste volume of 8.92 m^3, a total weight of 1510 kg, and having an average waste density of 170 kg/m^3 (Allen 1982). In this case, glove boxes are disposed of intact; in other cases size reduction is performed.

Overpack Container Cost

The overpack assumed for WIPP disposal is based on the Mound Laboratory (Dayton, Ohio) container design. This disposal container has a usable volume of 7.47 m^3 and weighs 907 kg.

Two glove boxes (8.92 m^3) will not fit into the disposal container; consequently, only one glove box weighing 757 kg is placed into an overpack container. The resulting waste packing density is 100 kg/m^3.

Assuming an annual waste volume of 180 m^3/year, based on newly generated metal waste at the Hanford site as given by Brown (1982), and 4.47 m^3 per glove box, the number of glove boxes disposed of per year would be 40.5. Values other than 180 m^3 could be used to derive the same unit costs ($/$m^3$); this number was used because it has been cited. The number of glove boxes disposed of annually are given in fractions because their disposal is not fixed by time.

The cost of an overpack disposal container is estimated to be about $3300. This is based on a manufacturer's price list and graphs for approved waste disposal containers of various volumes. For 40.5 containers the annual cost would be $134,000. The unit cost for containers using 180 m^3 of waste disposed annually would be $738/$m^3$ of original waste volume.

Certification Costs

It is assumed that the glove box waste is homogeneous and is certifiable when it is placed into the overpack disposal container. Glove box use history checks are estimated to take 2 manhours at $50 per manhour; three manhours are required to complete certification of each waste disposal container, in this case one overpack disposal container for each glove box. The total annual cost for certification would be \$10,000 or \$56/m^3 of original waste.

Interim Storage Costs

The volume of disposal containers placed into interim storage annually would be 360 m^3. The current unit cost for interim storage at the Hanford site is \$913/m^3. Thus the annual cost would be \$331,000 and the unit cost would be \$1830/m^3 of original waste.

Retrieval Costs

Waste retrieval costs are about \$1770/m^3. This gives an annual cost of \$640,000 or \$3530/m^3 of original waste volume.

Transportation Costs

Following retrieval, the certified waste would be shipped either by railroad or by truck to WIPP using the Transuranic Package Transporter (TRUPACT) system. Two overpack disposal containers with glove boxes can be placed lengthwise into a TRUPACT-I bimodal system having a cavity of 5.7 x 1.7 x 2.0 m and a weight of 15,000 kg (33,000 lb). The weight of a waste disposal container and a glove box would be 910 kg (container) + 757 kg (waste), for a total of 1670 kg. Two would weigh 2400 kg (7340 lb) for each TRUPACT. Two TRUPACTs having 4 overpack disposal containers can be shipped on a railcar. The number of railroad shipments required per year is 10.12 for 40.5 containers.

Railroad Transportation Costs

Railroad shipping costs are derived by the following equation:

$$\text{General-freight rail cost} = (\text{CVL} \times \text{LOAD}/100) + (\text{CVE} \times \text{EMPT}/100) + (\text{ESFGF} \times \text{DIS1})$$

where,

CVL = Loaded cask/container shipping cost approximation, \$/cwt[a]

= $0.1535 \times DIS1^{0.5860}$ (National)

CVE = Empty cask/container shipping cost approximation, \$/cwt

= $0.1405 \times DIS1^{0.5895}$ (National)

LOAD = Weight of full cask/container, lb

EMPT = Weight of empty cask/container, lb

ESFGF = Escort fee general freight (no escort used in this study)

DIS1 = Distance traveled

This equation gives a 1983 cost; this is escalated by a 1.05 factor to give a 1984 cost. The cost of one rail shipment (1510 miles or 938 km one way) of two TRUPACTs is:

$$= 2 \text{ TRUPACTs} \times 1.05 \times [0.1535 \times (1510)^{0.5860}] \times \frac{(33{,}000 + 734D \text{ lb})}{100 \text{ lb/cwt}} + 0.1405 \times (1510)^{0.5895} \times \frac{33{,}000 \text{ lb}}{100 \text{ lb/cwt}}$$

= \$16,800 per round trip

The approximate distance traveled per day for a distance of 1500 miles is 143 mi (Daling 1983, p. 5.5). This gives a round trip time of 21 days. Lease cost for TRUPACTs is \$800/day. For 2 TRUPACTs the total lease cost for 21 days would be \$33,600 per round trip.

Considering freight and lease costs the total annual cost for 10.12 shipments is \$510,000 which gives a transportation unit cost of \$2810/m^3 of original glove box volume.

Truck Transportation Costs

Truck shipping costs are derived by the following equation:

(a) cwt - abbreviation for hundredweight, a unit of weight used in commerce equal to 100 lb (45.4 kg).

Approximate truck freight cost = AA x LOAD + AB x EMPT
+ AEC x DIS4 + HRC
+ other factors

AA and AB are rates given in tables of the reference in cents per 100 lb for shipping waste specified distances. In this study the distance used is 1650 miles (1025 km) (a different route is used than that by railroad), AA = $7.98/cwt, and AB = $6.41/cwt. AEC = charge for an armed escort, $0.20/man-mile if required. In this study it was assumed that no armed escort is required and that this cost could be used for a second driver which would be needed. HRC = Highway route controlled material surcharge, $0.45/mile, one way. No other factors were used.

Only one TRUPACT can be shipped by a truck. The shipping cost of each round trip of 4 days would be about $6976. The TRUPACT lease cost would be $2800 per shipment to give a total transportation cost per shipment of $10,176. The annual cost for 20.25 shipments would be $198,000 which gives the unit cost of $1100/m^3 of original waste volume. Shipping by truck is less than half that of shipping by railroad. The truck shipping cost would rise if the daily travel distance were reduced.

TRU Waste Disposal Costs at WIPP

The WIPP operation costs have not been firmly established. However, a value used in preliminary estimates by a Rocky Flats Plant subcontractor is $773/m^3. This value is used in this study.

The outside dimensions of the overpack disposal container give a disposal volume of 9.0 m^3, or 360 m^3/yr for 40.5 containers. The annual cost for disposal is $280,000. This total gives a unit cost of $1550/m^3 of original waste volume.

Size Reduction Costs

No size reduction is performed in this case. However there are some miscellaneous handling activities that are included in this category. A unit cost updated from that by Allen (1982) of $46/m^3 of original waste volume is used.

Total Unit Costs

The annual costs calculated as described above are based on an annual waste generation volume of 180 m^3. This was used solely for calculating the unit costs, $/ft^3 of original glove box volume. For this case the estimated individual unit costs total $10,600/$m^3$ if waste is transported by railroad and $8900/$m^3$ if waste is shipped by truck.

CASE 2 DETAILS

Waste Form For Disposal

In this case glove boxes are disassembled and size reduced to about one half the original volume giving a packing density of about 350 kg/m^3.

Disposal Container Costs

The annual volume of waste disposed is reduced to 87 m^3 from the base of 180 m^3. The 1.7 x 1.4 x 0.97 m (DOT Type A) container has a usable volume of about 2.3 m^3. The number of containers required per year is 37.6. By using the same cost source for containers as in Case 1 a container cost is estimated to be $820. The annual container cost would be $30,800 for a unit cost of $170/$m^3$ of original glove box volume.

Certification Costs

The cost for glove box history checks would be the same as that for Case 1, $4050/year. The labor cost for 37.6 container/year (3 manhours/container, $50/manhour) would be $5640 to give a total certification cost of $9700 and a unit cost of $53/$m^3$.

Interim Storage and Waste Retrieval Costs

The external volume of the waste disposal container is about 2.4 m^3. The annual cost at $913/$m^3$ for 37.6 containers is $83,600 which gives a unit cost of $463/$m^3$ or original glove box volume. Similarly the retrieval costs at $1770/$m^3$ of stored volume is $893/$m^3$ of original glove box volume.

Transportation Costs

Eight disposal containers using volume as the basis could be placed into a TRUPACT; however, the maximum cargo weight for a TRUPACT weighing 15,000 kg is 7700 kg. Eight disposal containers, weighing 215 kg each empty, having a usable volume of 2.3 m^3 for waste having a density of 350 kg/m^3 would weigh 8270 kg. Thus only 7 containers weighing 7230 kg loaded can be placed into a TRUPACT. With the annual waste volume being 87.3 m^3, the number of railroad shipments using 2 TRUPACTs per shipment would be 2.69. If trucks were used the number of single TRUPACT shipments would be 5.37. Using the same equations as in Case 1 for shipping costs and adding TRUPACT lease costs, the annual costs are $141,000 for rail and $55,000 for truck. Unit costs are $777/$m^3$ for rail transportation and $300/$m^3$ of original glove box volume for truck.

TRU Waste Disposal Costs

The external volume of the disposal container is about 2.4 m^3. The annual cost for disposal of 37.6 containers at WIPP, using $773/$m^3$ of disposal volume, is $77,900. This gives a unit cost of $431/$m^3$ of original glove box volume.

Size Reduction

Allen (1982) gives $349/$m^3$ for size reduction. This value escalated to 1984 by using a 1.11 factor is $388/$m^3$ of original glove box volume. The two-year escalation factor is based on information from Chemical Engineering magazine and the Monthly Labor Review.

Total Unit Costs

For this case the estimated individual unit costs total $3200/$m^3$ if waste is transported by railroad and $2700/$m^3$ of original glove box volume if transported by truck.

CASE 3A DETAILS

Waste Form for Disposal

In this case glove boxes are reduced in size to about one-quarter of the original volume giving a packing density of 657 kg/m^3.

Disposal Container Costs

The annual waste volume is reduced to 47 m^3/yr from the base of 180 m^3. The waste is placed in 55-gal drums numbering 225 per year. The annual cost of drums costing \$60 each is \$13,500, and the unit cost is \$75/m^3 of original glove box volume.

Certification Costs

Glove box history checks remain the same for each case, \$4050/year. Certification labor for 225 drums (each certified individually at \$150) totals \$33,750 annually. These costs give a unit cost of \$209/m^3 of original glove box volume.

Interim Storage and Retrieval Costs

By Hanford site convention, 7.4 ft^3 (0.21 m^3)/55-gal drum is used to determine storage and retrieval costs. The costs for 225 drums annually are \$43,000 for interim storage and \$83,200/yr for retrieval. The unit costs are respectively \$237/m^3 and \$459/m^3 original glove box volume.

Transportation Costs

Using a volume of 0.208 m^3/drum, a waste density of 660 kg/m^3, and a drum weight of 31 kg, a loaded drum would weigh 167 kg. Since the cargo weight limit is 7700 kg, only 46 drums excluding dunnage can be shipped in a TRUPACT. The weight of dunnage is excluded in this study. This allows 92 drums to be shipped by railroad in two TRUPACTs. The annual number of rail shipments for 225 drums is 2.45. Using the same transportation equation and TRUPACT lease costs as in Case 1, the annual cost for shipping drums by rail would be \$129,000 for a unit cost of \$712/m^3 of original glove box volume. Truck transportation costs are derived similarly giving a unit cost of \$280/m^3.

TRU Waste Disposal Costs

The external volume of a 55-gal drum is about 0.25 m^3. If WIPP were to handle drums individually at \$773/m^3, the annual disposal costs for 225 drums would be \$44,300 for a unit cost of \$244/m^3 of original glove box volume.

Size Reduction

Allen (1982) gives a unit cost of \$1880/m^3 of original glove box volume for size reduction to place waste into 55-gal drums. The 1984 cost using labor costs indexes is \$2080/m^3.

Total Unit Costs

The total unit costs for this case are \$4020/m^3 if waste is shipped by railroad and \$3600/m^3 if shipped by truck.

CASE 3B DETAILS

Waste Form for Disposal

This case is similar to that of Case 3a in that size reduced waste would be placed into 55-gal drums. After retrieval from storage and before being shipped to WIPP the drums would be joined into six-packs by bracing. This cost is included in the cost of containers. The costs for size reduction, certification, interim storage, and retrieval are the same as those for Case 3a.

Disposal Container Costs

The cost for 225/year is \$13,500. Added to this is the cost of bracing at \$50 per six-pack. This is an escalated value from that used by Brown (1982). The total annual cost is \$15,400 which gives a unit cost of \$85/m^3 of original glove box volume.

Transportation Costs

Because of volume limitations only 6 six-packs of 55-gal drums can be placed into a TRUPACT. Thus a shipment of six-packs by rail car would consist of 72 drums in two TRUPACTs, and a shipment by truck, 36 drums in one TRUPACT. With bracing weighing 91 kg, the total six-pack weight would be 1090 kg. A loaded TRUPACT would weigh about 21,800 kg. The number of 72-drum rail shipments would be 3.12 annually; the number of 36-drum truck shipments would be 6.25 annually. The same equations used in Case 1 were used to calculate shipping costs. Shipping costs and TRUPACT lease costs give transportation unit costs of \$900/m^3 of original glove box by rail and \$350/m^3 by truck.

These unit costs could be decreased if other wastes than those considered here were added to a TRUPACT to improve the volume shipping efficiency.

TRU Waste Disposal Costs

Although the 55-gal drums of waste are collected into six-packs, the WIPP disposal costs are expected to be based on the external volume of the drums rather than that of the whole six-pack. Consequently, the unit cost for disposal would be the same as that for Case 3a, $244/m^3 of original glove box volume.

Total Unit Costs

The total unit cost if TRU waste is shipped by rail is $4200/m^3; by truck, $3700/m^3 of original glove box volume.

CASE 4 DETAILS

This case differs from the others in that sectioned glove box parts are decontaminated before disposal. The drummed material is handled as LLW instead of TRU waste and disposed of at the Hanford site rather than being shipped to WIPP for disposal. Waste data used were taken from Allen (1982).

Waste Form

Glove boxes are size reduced to essentially the same disposal volume as that of Cases 3a and 3b. Decontamination allows the bulk of the waste to be disposed of as LLW. Allen (1982) showed that 96% of the original waste volume is converted to LLW leaving 4% including secondary waste to be TRU waste.

Disposal Container Costs

Both the LLW and TRUW are disposed of in 55-gal drums. Using the same density as in Case 3a (660 kg/m^3) the number of drums required each year is 225. Nine of these drums would be used for TRUW, the remainder for LLW. The unit cost is the same as Case 3a: $75/m^3. Bracing cost for nine drums is negligible.

Certification Costs

The costs for glove box history checks would remain the same as before, \$4050, as this information will still be needed. The labor cost for certifying 9 drums would be \$1350 annually giving an annual cost of \$5400. The unit cost then is \$30/m^3 of original glove box volume.

Interim Storage and Retrieval

The same boxes as those used in Case 3a are used. This results in a unit cost of \$10/m^3 for interim storage of TRU waste drums and \$18/m^3 of original glove box volume for retrieval.

Transportation Costs

Drums placed into six-packs as in Case 3b would be transported to WIPP at the rate of 9 per year. This results in unit costs for transportation of \$36/m^3 for railroad and \$14/m^3 of original glove box volume by truck.

TRU Waste Disposal Costs

The annual cost for disposing of 9 drums is \$2400, or \$13/m^3 of original glove box volume. This assumes that the cost of WIPP disposal would remain the same, \$773/m^3 of waste volume disposed.

Size Reduction and Decontamination Costs

Allen (1982) gives a unit cost of \$2210/m^3 of original glove box volume for sectioning and decontamination. This cost is primarily for labor. It does not include capital recovery costs for facilities or maintenance costs. The 1984 unit cost using hourly earnings indexes is \$2450/m^3.

LLW Disposal Costs

The current charge at the Hanford site for non-transuranic waste disposal is \$191/m^3. The annual cost for disposing 216 drums having a disposal volume of 0.21 m^3 each is \$8,600. This gives a unit cost of \$47/m^3 of original glove box volume.

Total Unit Costs

The total unit costs (rounded) for this case are $2700/m^3$ of original glove box volume if TRU waste is shipped by railroad and $2700/m^3$ if the TRU waste is shipped by truck.

ALTERNATIVE CASE 4 - EFFECT OF CHANGES IN LLW DISPOSAL & TRANSPORTATION COSTS

LLW Disposal Costs for Several Sites

The unit cost for disposal of low level waste used in this study in Case 4 is the Fiscal Year (FY) 1984 cost at the Hanford Site, $191/m^3$. This excludes original packaging and transportation. The cost for disposal of LLW of low specific activity (LSA) at other sites differs from this depending on accounting and other practices, i.e., what is included or excluded from the cost. The following costs were obtained by telephoning cognizant people at several LLW generating sites.

The cost for LLW (LSA, less than 10 nCi/g) at Savannah River was reported to be $210/m^3$, using cardboard boxes for the waste which were in turn placed into metal boxes. This cost includes costs for trench preparation, boxes, and covering the trench following waste emplacement. It excludes costs for engineering (if any), real estate, and site closure.

A composite cost reported for Idaho National Engineering Laboratory is $560/m^3$. This includes disposal, storage, operation, and support costs, such as engineering staff and heavy equipment costs.

The disposal cost at Oak Ridge for LLW having a radiation dose rate of less than 200 mR/h is $275/m^3$. For LLW having dose rates exceeding 200 mR/h, the disposal cost can reach $4200/m^3$ depending on what has to be done with the waste.

LLW generated at Rocky Flats Plant is sent to the Nevada Test Site for disposal. The costs associated with this method are: $710/m^3$ for operations at Rocky Flats Plant, $42/m^3$ for transportation, and $88/m^3$ for disposal, giving a total of $840/m^3$.

A comparison of LLW disposal costs shows that these costs differ markedly among the sites. Consequently, a generic cost of $560/m^3$ for LLW disposal will be used in this alternative for Case 4 to show the effects of variance in this cost along with the cost impact of transporting the waste to a disposal site 805 km (500 miles) from the generation site.

LLW Disposal Cost

The annual cost for disposing of 216 55-gal drums (45 m^3) of low level waste at $560/$m^3$ is $25,000. The unit cost is $140/$m^3$ of original glove box volume.

LLW Transportation Cost

LLW would be transported by truck to the disposal site. A shipment would constitute 70 55-gal drums, placed one tier high, in a 12.2 m long trailer. The total cost for a one-way trip west of the Mississippi was calculated as follows:

$$\text{Cost} = \frac{\$2.21}{\text{mi}} \times 500 \text{ mi}$$

$$= \$1100$$

The annual cost for shipping 216 drums is $3400. This gives a unit cost for transporting LLW of about $19/$m^3$ of original glove box volume.

Total Cost for Alternative

The effect of the changes in LLW disposal cost rates and transporting LLW 500 miles for disposal is shown below:

Alternative Case 4 Unit Costs,
$/m³ of Original Glove Box Volume
(1984 Dollars)

	$\$/m^3$
Containers	75
Certification	30
Storage	10
Retrieval	18
TRUW Transportation (Rail)	36
TRUW Disposal (WIPP)	13
Decontamination	2450
LLW Disposal	140
LLW Transportation (Truck)	19
Total, Rounded	2800

The effect of changing LLW disposal and transportation costs is an increase in total cost for Case 4 from $\$2700/m^3$ to $\$2800/m^3$ of original glove box volume. Case 4 remains the best option of the cases given in Table 5. Transportation of TRUW by truck rather than by rail will have a minimal effect on this alternative for Case 4; a rounded total cost would be the same, $\$2800/m^3$, because of the relatively small amount of TRUW produced in this case.

Effect of Addition of Capital and Maintenance Unit Costs on Totals

Fixed annual capital and maintenance costs for needed facilities will impact the total unit costs. In Case 1 no size reduction occurs; thus, this type of facility is not required. In Cases 2 and 3 size reduction is used. Although the waste is reduced further in size in Case 3 than in Case 2, essentially the same size reduction facility would be used, and it would have about the same maintenance cost for the same throughput. In this treatment it is assumed that facility and maintenance costs would be identical for the two cases. In Case 4, size reduction and decontamination are performed; additional costs would be needed for decontamination.

The capital cost of the ASRF at Rocky Flats, \$9.6 million (1984), was used as a base for estimating approximate unit capital and maintenance costs for Cases 2, 3 and 4. The nominal capacity of the ASRF will allow processing of one glove box (<1.8 x 2.4 x 3.0 m) per eight hour shift to give greater than 50% reduction of waste shipping volume (Mitchell, Aguilar and Williams 1984). If it is assumed that a similar facility would operate for 180 days/year, 2300 m^3/yr of waste could be processed. Assuming additional costs of 6% for startup and R&D and 10% for decontamination and decommissioning (D&D) to give a total capital cost of $11.2 million, and assuming a 15-year facility lifetime, the unit capital or amortization cost for Case 2 would be $324/$m^3$ (unrounded). The maintenance cost at 3% of equipment and building costs/year would be $125/$m^3$. These two unit costs give an approximate size reduction capital and maintenance cost of $450/$m^3$ of original glove box volume for Cases 2 and 3.

Brown (1982, pp. A-5 and A-11) gives costs of $11.4 million and 4.0 million (1981 dollars) respectively for his generic size reduction and decontamination facilities. Using the ratio of 0.35 from these two costs and $9.6 million for the ASRF, the approximate cost for a decontamination facility capable of handling size reduced waste from the ASRF would be $3.4 million (1984 dollars). Adding 16% for startup, R&D, and D&D brings the total capital cost to $3.9 million. Assuming the same annual throughput, 2300 m^3/yr, and the 15-year facility lifetime, the approximate unit capital cost would be $113/$m^3$ (unrounded). The unit maintenance cost at 3% of equipment and building costs would be $44/$m^3$.

The incremental unit capital and maintenance costs (rounded) for Cases 2, 3 and 4 are given below:

	$/$m^3$ of Original Glove Box Volume
Cases 2 & 3 (size reduction)	450
Case 4 (size reduction & decontamination)	610

The effects of considering total capital and maintenance unit costs are shown in Table A.1 for both railroad and truck transportation modes.

TABLE A.1. Effects of Capital and Maintenance on Total Unit Costs of Alternative Processing Cases

Case	Unit Costs, $\$/m^3$ of Original Glove Box Volume (Rounded, 1984 dollars) Railroad	Truck
1	10,600	8,900
2	3,600	3,100
3a	4,500	4,000
3b	4,700	4,100
4	3,300	3,300

Case 1, in which neither size reduction nor decontamination is performed, is the least cost effective regardless of the mode of transportation. The most cost effective Case using railroad transportation is Case 4, in which glove boxes are size reduced and the parts decontaminated. If truck transportation is used, the most cost effective alternative is Case 2. However, the difference between Cases 2 and 4, as affected by the mode of transportation, is less than 10%.

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