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Decontamination System Study for the Tank Waste Retrieval System

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Decontamination System Study for the Tank Waste Retrieval System

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ABSTRACT

This report summarizes the findings of the Idaho National Engineering Laboratory's decontamination study in support of the Tank Waste Retrieval System (TWRS) development program. Problems associated with waste stored in existing single shell tanks are discussed as well as the justification for the TWRS program. The TWRS requires a decontamination system. The subsystems of the TWRS are discussed, and a list of assumptions pertinent to the TWRS decontamination system were developed. This information was used to develop the functional and operational requirements of the TWRS decontamination system. The requirements were combined with a comprehensive review of currently available decontamination techniques to produce a set of evaluation criteria. The cleaning technologies and techniques were evaluated, and the CO₂ blasting decontamination technique was chosen as the best technology for the TWRS.

SUMMARY

This document summarizes the findings of the Idaho National Engineering Laboratory's decontamination study in support of the Tank Waste Retrieval System (TWRS) development program.

The U.S. Department of Energy has established the TWRS program to remove hazardous wastes from the single-shell storage tanks. The TWRS will use a robotic long reach manipulator (LRM) to help remove the 1 to 2-ft thick sludge heel at the bottom of the tanks for transfer to safer double-shell tanks.

Operation of the TWRS will potentially lead to contamination of the LRM, the in-tank support systems (i.e., video cameras and lighting), supporting structures, and wastestream system from the SST to DST. To ensure that the hazardous materials are managed and contained, a decontamination system will clean equipment as they are removed from the tanks.

This study examines the scope of decontamination operations required, identifies potential decontamination methods capable of accomplishing that scope, documents each method's capabilities and limitations, defines the requirements of a decontamination system to satisfy the needs of the TWRS, and documents the findings that can be provided to vendors of the TWRS.

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ACRONYMS

ALARA	As low as reasonably achievable
CAAA	Clean Air Acts Amendment of 1990
DOE	U.S. Department of Energy
DST	Double shell tank
EEEM	End effector exchange module
HEPA	High efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LDUA	Light duty utility arm
LRM	Long reach manipulator
ORNL	Oak Ridge National Laboratory
RCRA	Resource Conservation and Recovery Act
SRS	Savannah River Site
SST	Single shell tank
WHC	Westinghouse Hanford Company
TWRS	Tank Waste Retrieval System

Decontamination System Study for the Tank Waste Retrieval System

1. INTRODUCTION

This document summarizes the findings of the Idaho National Engineering Laboratory's (INEL's) decontamination study in support of the Tank Waste Retrieval System (TWRS) development program.

The U.S. Department of Energy (DOE) has established the TWRS program to remove hazardous wastes from the single-shell storage tanks (SSTs). The TWRS will use a robotic long reach manipulator (LRM) to help remove the 1 to 2-ft thick sludge heel at the bottom of the tanks for transfer to safer double-shell tanks (DSTs).

Operation of the TWRS will potentially lead to contamination of the LRM, the in-tank support systems (i.e., video cameras and lighting), supporting structures, and wastestream system from the SST to DST. To ensure that the hazardous materials are managed and contained, a decontamination system will clean equipment as they are removed from the tanks.

This study examines the scope of decontamination operations required, identifies potential decontamination methods capable of accomplishing that scope, documents each method's capabilities and limitations, defines the requirements of a decontamination system to satisfy the needs of the TWRS, and documents the findings that can be provided to vendors of the TWRS.

1.1 Problem Statement

Underground waste storage tank, 241-C-106 (tank C-106), is a steel-lined, reinforced concrete, SST built in 1943, one of the first waste storage tanks of its kind. The SST is 75 ft in diameter with a storage capacity of 533,000 gal. The tank has been used for storage of relatively high-level radioactive waste since 1947 and contains 197,000 gal of sludge from many waste management and isotope recovery operations.

The waste in these tanks consists of two separate components: a relatively soft, viscous sludge, with a varying consistency that floats on a 1 to 2-ft thick hardened sludge heel at the bottom of the tank with a consistency similar to the salt licks used in the cattle industry. Sluicing technology adapted from the mining industry was used to retrieve waste from 43 SSTs between 1952 and 1978. Sluicing was effective at retrieving most of the soft sludge but could not retrieve the hardened sludge heel.

Westinghouse Hanford Company (WHC) has initiated two projects to retrieve the waste from tank C-106 and demonstrate waste retrieval technologies applicable to Hanford underground storage tanks in general. Project W-320 involves sluicing to retrieve the soft sludge from the SST, and Project W-340 develops the LRM for retrieving the hardened sludge heel.

Due to the nature of the environment in which the LRM will operate, it is possible that some radioactive contamination will adhere to it during waste retrieval activities. As the LRM is removed from the tank (e.g., for maintenance, decommissioning, or reuse), it will have to be decontaminated to comply with safety guidelines. The in-tank support systems, such as video cameras and lighting systems, will possibly become contaminated as well, and will also need to be decontaminated. In the course of transferring the waste from the SST to the interim storage tank and finally to the DST, it is possible that some of the support structures will become contaminated.

1.2 Work to Date

The Light Duty Utility Arm (LDUA) project uses a robotic manipulator, in a storage tank, to investigate, characterize, and map the interior of the tank. Although the operation of the LDUA will not be as rigorous as the LRM, the arm still needs to be decontaminated as it is removed from the tank. The INEL has been in charge of designing a decontamination system for the LDUA since 1991 and has invested significant resources into researching and investigating various decontamination techniques.

Based on the nature of the operations of the LDUA, and the design criteria imposed by WHC, the INEL decided that a CO₂-based decontamination system was the technique best suited for decontamination of the robot arm. However, the differences between the LDUA and LRM call for a reassessment of the decontamination technologies. The LRM will come into direct contact with the wastes in the tank, while the LDUA, which is purely an inspection tool, will not. This means the LRM decontamination system may need to be more abrasive than the LDUA system. In addition, the LRM will position end effectors that retrieve waste from the tank and transport it to a different location, while the LDUA will not. For this reason, the LRM decontamination system will have to consider possible contamination of the support structure and wastestream system, while the LDUA will not.

1.3 Design Approach

The design approach for the TWRS decontamination system will be to have two decontamination stations. A primary decontamination station that remains in a fixed location at the bridge/tank interface. The bridge/tank interface serves as a compliant connection between the tank riser and the rest of the LRM system, provides confinement of the tank atmosphere, and will house the primary decontamination system.

The objective of the primary decontamination system is to remotely dislodge and remove varied waste forms from the hardware deployed in the tank riser, without generating secondary waste during the process. The decontamination media should have minimum impact on the hardware, personnel, and environment. When operations in the tank have been completed, the mast, LRM, and end effectors will be automatically decontaminated while they are being withdrawn through the decontamination system. The decontamination system will perform its cleaning operations, reducing the level of contamination to an acceptable level. Once an acceptable level of decontamination has been reached, as determined by a set of radiation monitor sensors, the decontamination system will turn off.

A secondary mobile decontamination system that is manually operated will also be used. The objective of this secondary decontamination system is to dislodge and remove varied waste forms from hardware and structures that are not deployed in and around the tank riser to an acceptable level so they can be disassembled, removed, and/or transported to a cleaning facility without risk to equipment and personnel.

2. LRM PROBLEM STATEMENT

The TWRS will use the LRM to retrieve the sludge heel from tank C-106. It consists of 13 subsystems that, for the purposes of evaluating decontamination methods, can be organized into four distinct categories:

- LRM and associated systems
- In-tank support systems
- Supporting structure
- Wastestream system.

In this section, these categories are defined to give an overview of the complete system. Then a list of assumptions pertinent to the design of the decontamination system is reviewed. Finally, this information is synthesized to provide the distinct functional and operational requirements for each of the categories. This will provide a baseline for determining the decontamination system evaluation criteria.

2.1 Four Major Categories of Subsystems

For the purposes of evaluating decontamination methods, the TWRS can be broken into four categories of subsystems. The physical location of the subsystems in each category are shown in Figure 1. The categories are defined below.

2.1.1 Long Range Manipulator and Associated Systems

This category includes the following subsystems:

- Deployment Mast

The deployment mast provides rigid mounting and alignment features for operating the waste retrieval manipulator. The mast is actually lowered into the tank through a tank riser and will be in the tank vapor space. Tank vapor space is assumed to be the gaseous volume in an underground storage tank between the solid and/or liquid on the bottom of the tank to the dome of the tank.

- Long Reach Manipulator

The LRM is a 40-ft long, three section robotic arm attached to the end of the deployment mast. It is used to position the waste retrieval end effector anywhere inside the tank. The LRM will be in the tank vapor space.

Long Range Manipulator and Associated Systems

Supporting Structure.

Figure 1. Physical locations of TWRs subsystems.

In-Tank Support System

Waste Stream System

- End Effector

The end effector consists of a ring of high-pressure, low-volume water jets employed to break up the sludge heel in preparation for retrieval by vacuum (with the air conveyance system). The entrance to the vacuum is located in the center of the water jet ring and is part of the end effector. The end effector will come into direct contact with wastes stored in the tank.

- Bridge/Tank Interface

This subsystem serves as a compliant connection between the tank riser and the rest of the LRM system, allowing lateral and vertical movement of the LRM structure without transferring loads to the riser. It provides confinement of the tank atmosphere and will house the primary decontamination system (i.e., the system that decontaminates the LRM and associated systems).

2.1.2 In-Tank Support Systems

This category includes the camera and lighting system. The camera and lighting system is a video-based system used to provide the viewing needed to operate the LRM in the teleoperated mode. The system will be inserted into the tank through adjacent tank risers and will be in the tank vapor space.

2.1.3 Supporting Structure

This category includes the following subsystems:

- Bridge

The bridge is mounted on concrete foundations on either side of the tank and spans the tank. It supports all waste retrieval subsystems, with the exception of the utilities module, and is designed to limit stress on the tank.

- Support Tower

The support tower is a structural steel tower designed to enclose and support the retrieval equipment.

- Support Mast

The support mast is mounted inside the support tower and is part of the main support structure. It houses the deployment mast and LRM when they are retracted, and provides a second layer of confinement for the retrieval system.

- **End Effector Exchange Module**

The end effector exchange module is mounted directly below the support mast and provides an enclosed area in which to replace defective end effectors and perform minor maintenance on them.

- **Control Station**

The operation of the TWRS is controlled remotely. The system operator controls retrieval activities from a central control station containing video monitors and the control systems. The control station shall be isolated from the tank environment, where it is unlikely that the control station will ever become contaminated.

- **Utilities Module**

The utilities module is a ground-level building located near the tank that houses the auxiliary equipment needed to operate the TWRS. It is unlikely that the utilities module will ever come into contact with wastes stored in the tank or general area hazards.

- **Heating, Ventilation, and Air Conditioning (HVAC)**

The HVAC system controls the tank and TWRS air pressure and flow before, during, and after retrieval operations. Prefilters, HEPA filters, and ducting portions of the HVAC system have the potential of becoming contaminated. Prefilters, HEPA filters, and ducting that come in contact with contaminants will be decontaminated, handled, and/or replaced as required by existing WHC procedures and practices.

2.1.4 Wastestream System

This category includes the air conveyance system. This system pneumatically removes the waste from tank, mixes it with water in the waste accumulation tank, and then pumps it to the receiver DST. It consists of pumps, hoses, and waste accumulation tank (where the waste is diluted with water).

2.2 Assumptions

To determine the correct decontamination systems for the four categories, assumptions made during system evaluations must be documented. The following assumptions were used in evaluating decontamination systems:

- Project W-320 retrieved the soft sludge from the SST prior to any TWRS operations. The TWRS only retrieves the hardened sludge heel at the bottom of the SST (Project W-340).
- The tank is held at a negative pressure during all retrieval operations by the tank ventilation system supplied by WHC.
- The tank atmosphere may contain combustible gases such as hydrogen.

- Highly abrasive decontamination techniques may damage the equipment being decontaminated.
- Decontamination of the LRM and its associated systems will be the primary decontamination system function. The decontamination system will remove contamination to as low as reasonably achievable (ALARA) standards. Final in-depth decontamination activities will occur at the WHC cleaning facility.
- Decontamination of the in-tank support systems, support structure, and wastestream system being of secondary importance.
- Any contamination outside the tank will be the result of an unforeseen leak or system problem. This condition will be of minimal concern due to the secondary containment systems designed into the equipment, and therefore, can easily be handled manually with the secondary decontamination system.
- Cleaning media used during decontamination operations may be deposited in the tank, since the TWRS will remove it in subsequent operations.
- The waste accumulation tank (part of the air conveyance system) will hold 5,000 gal of waste before it must be processed and pumped to the receiving DST.
- The sludge heel will not contain high heat generating materials, and will be less radioactive than the sludge already removed (Evans, 1993).
- Some components of the TWRS may be decontaminated for decommissioning, while others may be reused in waste retrieval operations at other SSTs.
- The decontamination of the deployment mast, LRM, and end effector will primarily be performed remotely but will have the capability of being performed manually.
- The decontamination of the remaining categories of the TWRS may be performed solely on a manual basis.
- Regulatory permitting requirements will not be considered in the selection of a decontamination method.
- The LRM and associated systems will be designed to provide a smooth accessible geometry with minimal hidden surfaces to simplify decontamination.
- The remaining categories of the TWRS will be designed to provide a "decontamination friendly" geometry to simplify any manual cleaning operation that may be required. The hardware shall be able to withstand the pressures and forces of the secondary decontamination system.

- Some TWRS systems could be cleaned at the WHC decontamination facility, (e.g., WHC decontamination facility, Building 2706T), but this study only addresses systems that need to be, or can only be, decontaminated at the tank farm.

2.3 Functional and Operational Requirements

The functional and operational requirements of the TWRS can be best addressed by considering each of the four different categories of subsystems separately. Each category has unique attributes that will determine the best decontamination technique to use.

2.3.1 Long Range Manipulator and Associated Systems

The subsystems in this category will be inserted into the tank and will be in the vapor space of the tank. The decontamination system shall be located inside the bridge/tank interface to decontaminate the LRM each time it is withdrawn from the tank. This requirement is similar to the LDUA decontamination requirements, except any secondary waste produced by the decontamination procedure can be returned to the tank, since the tank waste will be retrieved later (although this may not be desirable due to economic and secondary waste considerations).

The functional and operational requirements of the decontamination technique for the LRM and associated systems are as follows:

- Capable of being decontaminated to ALARA standards
- Capable of removing both smearable and fixed contamination
- Generate a minimum of secondary waste
- Nonsparking and nonheat generating
- Capable of being operated either remotely or manually
- Nondestructive to the equipment
- Use proven technology
- Easy to operate and maintain.

2.3.2 In-Tank Support Systems

Subsystems in this category will also be inserted into the tank vapor space, the requirements differ slightly from the previous category because the camera and lighting system are deployed through a different riser and will only have to be removed from the tank once. Barring the chance that the camera and lighting system will require maintenance, the only time they need to be removed from the tank is when the project is completed and they need to be decontaminated for eventual reuse or for permanent decommissioning. Any secondary waste produced from the decontamination

procedure can be returned to the tank, since the tank waste will be retrieved later (although this may not be desirable due to economic and secondary waste considerations).

The functional and operational requirements of the decontamination technique for the in-tank support systems are as follows:

- Capable of reducing contamination levels to ALARA standards
- Capable of removing both smearable and fixed contamination
- Generate a minimum of secondary waste
- Capable of being operated either remotely or manually
- Safe for personnel
- Be nondestructive (if the equipment will be reused)
- Use proven technology
- Easy to operate and maintain.

2.3.3 Supporting Structure

The subsystems in this category will not be inserted into the tank and will not come into direct contact with contaminants unless an unforeseen problem arises. Therefore, almost any type of equipment has the potential to become contaminated. For this reason, a decontamination technique that can be used in a variety of circumstances is required. The decontamination technique must also consider that the contamination is likely to occur outside of any confined space.

The functional and operational requirements of the decontamination technique for the supporting structure are as follows:

- Capable of reducing contamination levels to ALARA standards
- Capable of removing both smearable and fixed contamination
- Generate a minimum of secondary waste
- Operated manually
- Safe for personnel
- Nondestructive (if the equipment will be reused)
- Use proven technology

- Easy to operate and maintain
- Mobile system, capable of moving to different hardware locations
- Provide for some kind of temporary containment enclosure (since the contamination will most likely occur "outside"), or have a capture method that will be used simultaneously during cleaning operations.

2.3.4 Wastestream System

The subsystems in this category will not be inserted into the tank and will not come into direct contact with contaminants unless an unforeseen problem arises. As this is the case, almost any type of equipment has the potential to become contaminated. For this reason, an adaptable decontamination technique that can be used in a variety of circumstances is required. Also, the decontamination technique evaluation must consider that the contamination is likely to occur outside of any confined space.

The functional and operational requirements of the decontamination technique for the wastestream system are as follows:

- Capable of reducing contamination levels to ALARA standards
- Capable of removing both smearable and fixed contamination
- Generate a minimum of secondary waste
- Operated manually
- Safe for personnel
- Nondestructive (if the equipment will be reused)
- Proven technology
- Easy to operate and maintain
- Mobile system, capable of moving to different hardware locations
- Provide for some kind of temporary containment enclosure (since the contamination will most likely occur "outside"), or have a capture method that will be used simultaneously during cleaning operations.

3. SURVEY OF DECONTAMINATION TECHNIQUES

Numerous decontamination technologies have been used throughout the DOE complex in a variety of different decontamination scenarios. Certain decontamination techniques are better suited for particular situations than others. For example, the vibratory decontamination technique, in which objects are placed in a tub of abrasives in a chemical solution and vibrated to remove contamination, may be well suited to decontaminating loose tools but would be ineffective in decontaminating a concrete wall.

The following section briefly describes the major decontamination technologies used at the various DOE sites. In Section 4, these techniques are evaluated considering the specific requirements of the TWRS.

3.1 Descriptions of Available Decontamination Technologies

This section of the report describes and summarizes the various decontamination techniques evaluated.

3.1.1 Abrasion

Abrasive cleaning is an effective method of removing adhered surface contamination. Three variations of abrasive cleaning are available: dry blasting (sandblasting), shot peening, and solution grit (slurry jet) blasting. Blasting pressures for the dry grit process are expected to be less than 100 psi, while solution grit blasters may exceed 1,000 psi. Dry blasting equipment is relatively simple and inexpensive. However, this method generates contaminated airborne particulates during cleaning that poses a risk to personnel safety as well as a risk of recontamination. Slurry jet blasting provides improved recontamination control and simplifies waste cleanup. Shot peening can be an effective cleaning method; however, it can damage sensitive equipment.

Abrasive cleaning can be used on large cell applications with remote equipment, or in enclosed, glove box-type units. Generally, this application is limited to the decontamination of metal items as recontamination occurs with softer or porous materials. This decontamination technique is relatively easy to use, can usually provide a visual indication of object cleanliness to the operator, can be labor intensive if performed manually, and can be expensive. Spent radioactively contaminated grit can be dried and grouted. Significant secondary waste is created when using this method.

3.1.2 Chemical

The decontamination of equipment using chemicals is one of the most widely used decontamination techniques. Chemical washing provides contamination removal from the interior and exterior of equipment, cracks, porous materials, and otherwise unreachable locations. However, chemical washing has lost favor within the industry due to the fact that recent enacted Environmental Protection Agency (EPA) regulations resulted in permitting and waste disposal difficulties. Chemical regeneration and recycling offers the potential for resolving these concerns. Chemical washing has proven to be relatively inexpensive and effective, although the use of hazardous chemicals does present some personnel safety concerns.

3.1.3 CO₂ Blasting

The carbon dioxide cleaning technology (CO₂ blasting) was originally developed by the aerospace industry to clean and repaint large commercial aircraft. While the use of CO₂ for surface preparation dates back almost 20 years, it is only recently that the technology has been developed to the point where it is commercially available as a decontamination alternative.

The CO₂ cleaning process introduces dry ice particles (either snow or pellets approximately the size of a grain of rice) into a high velocity stream (typically air). This high velocity stream propels these particles of dry ice toward the surface of the substrate, that upon impact sublime (i.e., change from a solid to a gas), leaving only the removed contaminants for disposal. By adjusting the media parameters (size, velocity, and quantity), it is possible to safely clean a wide spectrum of surfaces and materials ranging from plastic films to steel ship hulls. When used properly in well-ventilated, nonradioactive environments, CO₂ blasting requires no special gear for handling other than adequate protection against skin and eye contact to prevent freezing of tissues.

The dry ice particles are manufactured by taking liquid CO₂ and expanding it to atmospheric pressure. The resulting product is CO₂ snow. This dry ice snow can then be used as the cleaning media or can be compressed into a pellet of predetermined shape and density. It is essential when using this technology in an enclosed environment that a well designed high efficiency particulate air (HEPA) filter system be incorporated into the design. A HEPA intake must be close to the blasting area with sufficient surface area and intake velocity to capture the high velocity contaminants as they are being blasted off. Routine or constant monitoring of the HEPA system is necessary as the contaminants may concentrate in the filters. The fact that CO₂ is 1.5 times heavier than air should assist in keeping the airborne activity confined to the lower areas of the enclosure. Therefore, it is recommended that a floor, scavenger-type HEPA system be incorporated into the design. As CO₂ displaces air, oxygen levels within the enclosure will vary depending the degree of ventilation in the area.

A number of technology programs over the last few years have demonstrated that CO₂ cleaning is an extremely effective method of decontaminating objects of a variety of materials and configurations. Decontamination activities include hot cell decontamination, paint removal, and tool and equipment cleaning.

The cleaning action of CO₂ blasting results primarily from momentum transfer between the pellets and particulates when the dry ice particles impact the object surface and sublime. Secondary cleaning results from the thermal-mechanical shock (the CO₂ is generally significantly cooler than ambient conditions) and through reverse fracturing. Some cooling of the substrate takes place but is not expected to exceed a decrease of 40°F. The likelihood of damage due to cooling is remote. Reverse fracturing is the process by which the solid and liquid CO₂ molecules enter through the pores of the contaminant. As the molecules turn into a gas and begin to warm up, the expanding gas will push the contamination from underneath, further assisting in the removal process. The collisions loosen particles from the surface where they are entrained in the gaseous CO₂ and swept away from the surface, leaving only the removed contaminant for disposal. The decontamination method itself does not generate any additional waste. CO₂ cleaning is cost effective because liquid CO₂ is readily available and inexpensive. An additional advantage of this technology is the cost savings resulting from the elimination of the secondary waste generation currently associated with industrial cleaning

technologies such as hydrolasing and grit blasting. CO₂ cleaning is also time efficient compared with competing liquid spray cleaning methods, which require prolonged spray times. CO₂ cleaning is nondestructive, nonsparking, nonheating, and environmentally acceptable. CO₂ is a nonconductive medium, ideally suiting it for electrical applications. It is nonreactive and nearly inert, making it compatible for use in reactive environments, such as highly flammable hydrogen gas. CO₂ does not become radioactive when cleaning radioactively contaminated hardware. At the end of the process when the CO₂ sublimates to the atmosphere, its release is not regulated under the Resource Conservation and Recovery Act (RCRA) or the Clean Air Act Amendments (CAAA) of 1990.

3.1.4 Electropolishing

Electropolishing of metals, essentially the opposite of electroplating, works by the same electrochemical process. The process can be performed in situ or ex situ and does not affect the metal surface layer (the crystalline structure). The object being decontaminated generally serves as the anode and is submerged in an electrolytic solution. The passage of electrical current results in the progressive anodic dissolution of the surface material and removal of the majority of radioactive contamination. In certain situations when the surface can be passivated, the object surface must serve as the cathode. Surfactants are used as foaming agents that suppress the spattering of solution caused by gas evolution. Hydrogen gas explosion potential does exist and sufficient safety precautions must be taken. If bath purity is a concern to minimize recontamination, then high waste volumes can be expected because the bath solution must be changed frequently. High equipment costs are also a concern.

Electropolishing does have some definite limitations as a decontamination technique. Although the throwing power of electropolishing solutions is good, the ability to remove contamination from deep cracks, crevices, holes, and other areas that are shielded from the cathode is limited, unless the geometry is favorable for the use of an internal cathode. The surfaces to be decontaminated must be conductive and free of paint, grease, tape, heavy layers of corrosion products, and any other surface material that might inhibit the electropolishing action.

3.1.5 Freon

Freon decontamination methods were not considered in this survey because of the industry ban on the use of fluorocarbons.

3.1.6 Hand Wiping

Wiping and hand scrubbing methods were not addressed in this survey because they are well established methods of decontamination that result in high personnel radiation exposure and are labor intensive.

3.1.7 Hydrolasing

Cleaning of equipment and facilities using hydrolasing is well established decontamination technique. High-pressure water from 1,000 to 20,000 psi is sprayed at the object to be decontaminated to remove the surface contamination. Hydrolasing can be performed in situ, ex situ, or remotely. This method is not a finishing technique and should not be used on concrete or soft

materials because of the amount of surface material that would be removed. Hydrolasing produces large volumes of waste water that requires additional processing. One advantage of hydrolasing is that no chemicals are used. Therefore, there are no additional safety concerns with respect to hazardous chemicals. Surfactants, caustic solutions, and chemical cleaners have been added to the hydrolasing water to increase the solution's depth of penetration and the method's overall effectiveness. This high-pressure, chemically-enhanced method could also involve solvents such as acetone to dissolve desired contaminants. Development and testing of these decontamination enhancements could help reduce the amount of waste generated, but chemical safety and regulatory requirements must be considered. Hydrolasing also presents a pressure related safety concern and potential for higher radiation exposure to personnel because it is labor intensive.

3.1.8 Ice Blasting

The ice blasting or "wet ice" blasting process was originally conceived for aircraft depainting and has produced excellent decontamination factors during tests at Oak Ridge National Laboratory. This technology uses low-pressure air and ice chips to readily remove radioactive contamination or surface coatings through the processes of momentum transfer, crack formation, and propagation without resulting in substrate damage. A high level of decontamination was evidenced on stainless steel, carbon steel, wood, rubber, concrete, plastic, lead, copper, aluminum, and coated surfaces. Ice blasting uses water as its medium, and generates approximately 15 gal of waste water per hour.

The ice blasting system is portable, though equipment intensive, and must be used in a controlled area. The ice maker, refrigeration unit, ice sizing unit, air compressor, and generator can be located outside the area being decontaminated. Only the nozzle and hose assembly, which can be controlled remotely, are located in the area being decontaminated.

3.1.9 Light Ablation

Surface contamination and coatings may be removed by this technique. Light pulses can heat a surface film to 1,000 to 2,000°F in microseconds, while the substrate remains virtually unaffected. The light pulse decontamination mechanism occurs in three phases: sublimation or vaporization of the contamination (absorption of the light energy by the contaminant), ablation or thermal-mechanical shock (stress fracturing ejects solids from the surface), and scouring (vapors and particles ejected by previous processes scour the nearby surfaces). This method has been applied to remove epoxy paints, adhesives, corrosion products, and airborne and surface pollution. Light ablation is currently being developed for radioactive decontamination.

Several advantages and disadvantages accompany this technique. The effectiveness of light ablation can be substantial, potentially removing surface contamination completely for clean release. This decontamination technique also demonstrates waste minimization potential since secondary waste generation is limited to the off-gas filtering system that is required. By using remote equipment or robotics, personnel radiation exposure is lowered. However, the technique may be expensive, because development for radioactive decontamination is currently limited. Also, a number of personnel safety concerns exist, such as exposure to acoustic shock (noise), which can approach 90 dB, exposure to laser light, and exposure to high voltages. Problems dealing with removal of radioactive vapors and ablated material through exhaust systems are anticipated and are currently being examined.

3.1.10 Plastic Beads

Plastic bead or particles are propelled at the object in a 20 to 80 psi stream of dry air. The impact of the beads removes contamination. This technique is often used to clean contaminated hand tools in the nuclear industry. The beads produce a "wiping," rather than a "biting" action, limiting effective removal of fixed contamination. Glass or aluminum oxide beads can be used (in place of the plastic beads) to remove fixed contamination, but the beads cannot be recycled, and damage to sensitive components may occur. A relatively small amount of plastic is used if the beads can be recycled (i.e., in enclosed, controlled environments); however, when oily, dirty, or greasy objects are cleaned, the plastic cannot be recycled. This technique produces solid contaminated waste. The beads are certified incinerable. The beads will not damage sensitive equipment. This technique is often combined with other techniques to remove both fixed and smearable contamination.

3.1.11 Scabbling and Spalling

Scabbling (i.e., pummeling that results in scarification or chipping) and spalling (i.e., breaking off in layers) are proven concrete surface removal techniques. About 2.5 cm of the surface can be removed with scabbling or scarification equipment. Most of the surface contamination in concrete can be completely removed using inexpensive equipment. If deeper contamination exists, spalling methods involving drilling and slicing into the surface can be employed. By removing the entire surface, these methods can accomplish concrete decontamination more efficiently than most other techniques, often resulting in clean release of the residual concrete. However, problems do exist. Since both methods rely mostly on operator, "hands-on," labor intensive work, larger radiation exposures can be expected. Contaminated concrete dust and rough surfaces will be produced, resulting in the potential for recontamination of the cleaned surfaces. Since the concrete surface is roughened, it will require resurfacing or sealing if reuse is required.

3.1.12 Steam Jet

High-pressure steam is sprayed to remove surface contamination. This method should not be used on concrete or soft materials; the same general surface considerations as hydrolasing are involved. Disadvantages of steam jet cleaning are the personnel safety concerns working with high pressures and temperatures, working in high-radiation exposure environments, and creating large volumes of liquid waste. However, the radiation exposure and waste volume generated are typically lower than with hydrolasing. Steam jet cleaning also has the advantage over hydrolasing of surface thermal shock (immediate local material expansion or contraction) to assist in decontamination. This method tends to be labor intensive.

3.1.13 Strippable Coatings

Loose contamination may be removed by using selected strippable coatings. If contamination is not bound to a surface, then "fixing" it with a strippable coating (e.g., latex paint) that is easily removed from the surface creates an avenue for decontamination. Coatings can be applied by spraying or brush/roller equipment. These coatings are used both as protective coatings to prevent contamination and as a means of removing contamination from surfaces. Advantages of the technique are minimizing area contamination spread by spray application to quickly fix contamination and an initial reduction in radiation exposure compared to hand scrubbing. Small amounts of

secondary waste are generated, but most strippable paints are considered nonhazardous. Hand work required to remove the coating offsets potential decreases in radiation exposure except in areas of low radiation fields, or when hydrolasing is used to remove the paint.

3.1.14 Vibratory

The vibratory decontamination process takes place in a vibrating tub of loose media (e.g., ceramic or metal) through which flows a chemical solution or water. The energy from the tub (i.e., ultrasonic) causes the media to scrub the surfaces of the objects being decontaminated, while the liquid compound flushes away the material removed by the scrubbing action. The liquid solution used can also be designed to use chemical reactions to assist in decontamination. Materials that can be effectively decontaminated include: stainless steel, carbon steel, glass, rubber, Plexiglas, and miscellaneous plastics. The process is an ex situ process and may require cutting materials to a length necessary to fit into the tub. The solution can be recycled, but filter plugging problems and greater potential for recontamination result when compared to a single-pass-through process. Vibratory cleaning is relatively time consuming. Two other limitations should be noted: (1) soft metallic surfaces gain in fixed contamination, though there will be no detectable smearable contamination (i.e., contamination becomes impregnated), and (2) some chemicals will allow recontamination or deposition on the vibrating media that can then recontaminate. This technology is capital intensive but yields low personnel radiation exposure when compared to other decontamination techniques.

DOE sites where the decontamination techniques have been used are provided in Table 1.

Table 1. Sites where decontamination techniques have been used.^a

	Hanford	INEL	LANL	ORNL	RFP	SRS	West Valley
Abrasion	X	—	—	—	—	X	—
Chemical	—	X	—	—	—	X	X
CO ₂ blasting	—	X	—	X	X	—	—
Electropolishing	X	—	—	—	—	X	—
Freon washing	X	—	—	—	—	—	—
Hand wiping	—	—	—		—	—	X
Hydrolasing	—	X	X	X	—	X	X
Ice blasting	—	—	—	X	—	—	—
Light ablation	X	X	—	—	—	—	—
Plastic beads	—	—	—	—	—	—	—
Scabbling/spalling	—	—	—	—	—	X	X
Steam jet	—	X	—	—	—	—	—
Strippable coatings	—	X	—	—	—	X	—
Vibratory	X	—	—	—	—	X	—

a. Hanford—Hanford site

INEL—Idaho National Engineering Laboratory

ORNL—Oak Ridge National Laboratory

RFP—Rocky Flats Plant

SRS—Savannah River Site

4. DECONTAMINATION TECHNOLOGY EVALUATION

Although there are many ways to clean contaminated objects, only one technique will be chosen as the primary decontamination method used by the TWRS. In this section, the criteria used in evaluating the various decontamination methods are defined. The techniques are then compared based on these criteria. Through this comparison, the best system for use as the primary TWRS decontamination system will be determined.

4.1 Evaluation Criteria

There are a wide range of criteria that should be used in the comparing various decontamination techniques. Figure 2 below presents evaluation criteria in a logical breakdown structure.

The following list contains a subset of the criteria presented in Figure 2. Although these criteria will be used for evaluating the various decontamination technologies in a quantifiable manner, the entire set of evaluation criteria will be considered reaching a final decision. Section 4.2 will investigate these criteria as they pertain to each decontamination method. The evaluation criteria reflect the fact that the primary application of the TWRS decontamination system is to clean the LRM.

- **Removes smearable contaminants**—The effectiveness of the technology at removing smearable contaminants. A system that cannot remove smearable contaminants will not be considered for use with the TWRS.
- **Removes fixed contaminants**—The effectiveness of the technology at removing fixed contaminants. A technology that cannot remove fixed contaminants will not be considered for use with the TWRS.
- **Equipment risk**—Is the decontamination method destructive to equipment (metals, electronics, lenses and robotics)? A system that damages critical components will not be considered for use with the TWRS.
- **Generates gaseous wastes**—Is gaseous waste generated? Is oxygen displaced by off-gasses? Gaseous waste generation generally requires special ventilation equipment. A system that generates an excessive amount of gaseous waste may not be economical to use with the TWRS.
- **Generates liquid wastes**—Is liquid waste generated? Liquid waste generation generally requires special drainage equipment. A system that generates an excessive amount of liquid waste may not be economical to use with the TWRS.
- **Generates solid wastes**—Is solid waste generated? Solid waste generation generally requires special collection and/or ventilation equipment. A system that generates an excessive amount of solid waste may not be economical to use with the TWRS.

Figure 2. Decontamination system design considerations.

- **Generates mixed wastes**—Is mixed waste generated? Mixed waste generation generally requires special permitting, disposal equipment, and operations. A system that generates an excessive amount of mixed waste may not be economical to use with the TWRS.
- **Remote operation**—Can the decontamination system in its current state of development be operated remotely? A system that can be operated remotely is desired for many applications.
- **State of development**—How far is the state of development with respect to the TWRS? Particularly, has development work been performed to implement automation and remote operation? A system that has already had extensive development work to automate and remotely operate is desirable.
- **Onsite utilities**—Can onsite utilities be used for system operations? Do special needs exist? A system that can be operated solely from onsite utilities is desirable.
- **Simplicity**—The simplicity of the set-up and operation of the decontamination system relative to other systems. A system that is simple to set-up and operate is desirable.
- **Preventive maintenance**—Is regular preventive maintenance required for steady operation? A system that requires little or no preventive maintenance is desirable.
- **Safety**—Does operation of the equipment pose a threat to worker safety? Are special equipment and/or clothing required for operation of the system? A system that poses a minimal threat to worker safety and requires minimal special safety gear is desirable.
- **Application(s)**—How, where, and on what can a particular decontamination technology be used. If a technology can not be directly applied to the TWRS, it will not be considered for use with the TWRS.
- **Advantages**—General advantages of the method with respect to the TWRS.
- **Disadvantages**—General disadvantages of the method with respect to the TWRS.
- **Comments**—General comments on the method with respect to the TWRS.

4.2 Evaluation Matrices

Table 2 summarizes the evaluation of the different decontamination techniques based on the chosen evaluation criteria. A detailed examination of each respective technique appears in Appendix A. The evaluation criteria appear vertically along the left side of the matrix, and the decontamination techniques appear horizontally across the top. Each evaluation criterion has been assigned a weight percentage that represents the relative importance of the criterion in the final decision. The sum of these weight factors totals 100%. The entries in the matrix are based on a rating scale from 0 to 10, representing the relative desirability of a submission for a particular entry. A rating of 0 represents the least desirable submission, while 10 represents the most desirable. For example, a technique that can remove all smearable contaminants will receive a rating of 10 (the most

Table 2. Decontamination technique evaluation matrix.

	Weight factor (%)	Abrasion	Chemical	CO ₂ blasting	Electro- polishing	Freon washing
Smearable contaminants	20	10	10	10	10	10
Fixed contaminants	20	5	8	10	10	8
Equipment risk	20	0	3	10	3	10
Gaseous wastes	2	10	3	5	3	3
Liquid wastes	6	5	1	10	1	10
Solid wastes	6	3	8	10	5	10
Mixed wastes	6	3	1	10	1	10
Remote operation	2	10	5	10	10	10
State of development	6	5	1	9	1	6
Onsite utilities	2	10	10	8	10	8
Simplicity	2	8	8	8	8	8
Preventive maintenance	2	4	6	6	6	6
Safety	6	5	3	8	5	8
Total		5.10	5.68	9.56	6.12	8.94

Hand wiping	Hydro- lasing	Ice blasting	Light ablation	Plastic beads	Scabbling/ spalling	Steam jet	Strippable coatings	Vibratory
10	10	10	10	10	10	10	10	8
10	5	10	0	8	10	0	0	8
10	3	10	3	10	0	3	10	5
3	10	10	3	10	10	10	10	5
1	3	4	10	10	10	3	10	1
8	10	10	10	5	0	10	3	0
3	10	10	10	10	10	10	10	10
0	10	10	10	10	0	10	0	5
0	6	6	1	6	1	6	0	1
10	10	10	10	10	10	10	10	10
9	8	8	6	8	9	8	10	8
10	6	6	6	6	6	6	10	6
3	5	9	5	9	8	5	5	5
7.54	6.52	9.22	5.46	8.88	6.44	5.52	6.48	5.90

desirable submission for that particular evaluation criterion), but if it is incapable of removing smearable contaminants, it will receive a rating of 0 (the least desirable submission).

The weighing factors are used to calculate a rating that reflects the relative desirability of a particular technique when considered as a whole. This rating is labeled as TOTAL and appears horizontally across the bottom of the matrix.

4.3 Comparison of Decontamination Technologies

An evaluation of the decontamination technologies reveals that most methods currently available are not compatible with use on the TWRS. The two methods that best meet the TWRS requirements are CO₂ pellet blasting and ice (H₂O) blasting. This subsection compares these two technologies in more detail to decide which one is best suited for use with the TWRS.

Both CO₂ blasting and ice blasting have many qualities that are desirable to include in the TWRS decontamination system. They are both capable of removing smearable and fixed contaminants. Both techniques are nondestructive and will not harm sensitive equipment. Neither technique produces secondary solid or mixed waste. Both techniques can be remotely operated, are relatively simple to operate, and require a relatively small amount of preventive maintenance to operate effectively. There are, however, some important differences in the operation of the CO₂ blasting decontamination technique as compared to the ice blasting technique.

One advantage that ice blasting has over CO₂ blasting is that it produces no gaseous waste. This makes it slightly easier to use in confined areas because a dedicated ventilation system is not required for worker safety. Since CO₂ is heavier than air, it displaces air in confined spaces, thus reducing oxygen available for workers to breath and resulting in a safety hazard. The primary use of the decontamination system is to clean the LRM in a remote or completely autonomous operation. Workers will not be exposed to this danger on a regular basis.

There are two clear advantages that CO₂ blasting has over ice blasting; it is nearly fully developed for this specific application (through work performed in conjunction with the development of the LDUA), and it produces no liquid wastes. The lessons learned in the development of the LDUA decontamination system will result in a shorter development time for the TWRS decontamination system with fewer unknowns. The fact that it produces no liquid waste may seem inconsequential in lieu of the fact that any secondary waste generated during decontamination can be exhausted back into the tank, but there are some real benefits to avoiding introduction of secondary waste into the tank, especially liquid waste that can be difficult to contain.

Any secondary waste created, even if it is initially exhausted back into the tank, will eventually have to be treated in some way. If the secondary waste is removed to the DST along with the sludge heel, it is simply occupying a volume that can be used more effectively for storage of some existing waste. Also, any secondary waste exhausted to the tank during dismantling of the TWRS will not be retrieved from the tank and pumped to the DST, since the LRM will not be operational at this time. Some potentially significant amount of liquid secondary waste will be sitting in the SST with the potential to leak into the surrounding earth, which is what the TWRS was built to avoid in the first place. A bigger advantage of producing no liquid waste is realized when considering the decontamination of the support structure or wastestream system.

If a leak occurs and the support structure or wastestream system is contaminated, it will have to be contained and cleaned manually. In this case, it is assumed that provisions will be made to use the existing decontamination equipment to the greatest extent possible, perhaps by running a hose and nozzle from the existing CO₂ pelletizer unit or ice making unit to the contaminated area. This will also require some type of temporary containment of the contaminated objects (perhaps in the form of a tent-like or similar structure)^a. This containment structure will have to prevent the unplanned release of secondary waste by exhausting all the waste to either the tank (for ice blasting), or through HEPA filters to the atmosphere (for CO₂ blasting). Running a temporary waste exhaust hose from the contaminated area back to the tank introduces an unnecessary risk of further leaks and contamination, when the waste could simply be filtered and exhausted to the atmosphere. In either case, some type of ventilation will be required in the containment structure, so no special provisions are needed if the CO₂ blasting system is used.

After taking a closer look at the issues involved in choosing a decontamination system for the TWRS, it is clear that the best choice is a CO₂ blasting system.

a. In the recent "Call for Technical Task Plans FY95" issued by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Office of Technology Development, December 1993, the needs statement, DD-13 calls for an "Improved, Reusable Modular Containment System." When this technology is developed, it will be ideally suited for temporary containment of the type mentioned above.

5. VENTILATION

The INEL has been in charge of designing a decontamination system for the LDUA since 1991 and has invested significant resources into researching and investigating the various aspects of CO₂ decontamination techniques. Based on this experience, a ventilation system will be required to provide full time ventilation to the decontamination system enclosure during CO₂ cleaning operations.

The primary function of the ventilation system is to ensure that the atmosphere within the cleaning enclosure (including the tank atmosphere) is adequately isolated from the earth's atmosphere at all times and to carry away and trap contaminated airborne particulate generated during the decontamination process. The ventilation system would likely be a skid-mounted mobile unit built to specification and provide all the required equipment such as fans, motors prefilters, HEPA filters, ducting, and exhaust stack. The sizing and configuration of the unit would depend on the ventilation scenario that is implemented.

6. CONCLUSIONS AND RECOMMENDATIONS

The DOE has established the TWRS development program to investigate the effectiveness of using LRMs to retrieve this waste, a TWRS will be constructed to retrieve the waste from the SST, C-106 at Hanford. A significant portion of the development of the TWRS will focus on the decontamination system.

This report has incorporated a review of the major TWRS subsystems and listed assumptions pertinent to the decontamination of these subsystems to arrive at the functional and operational requirements for the TWRS decontamination system. This information was incorporated with a comprehensive review of available decontamination techniques to arrive at a list of evaluation criteria. These criteria were used to evaluate the various decontamination techniques to determine the technique best suited for use with the TWRS. The CO₂ blasting decontamination technique was chosen as the best technique to use in the TWRS decontamination system.

The following list summarizes the benefits of the CO₂ blasting decontamination technique over other techniques:

- Removes smearable and most fixed contaminants
- Nondestructive to sensitive equipment
- Creates no secondary liquid, solid, or mixed wastes
- Can be operated remotely
- Extensive related development experience with the LDUA
- Simple to operate and maintain
- Extremely safe under normal operating conditions.

The CO₂ blasting decontamination technique has some additional benefits that make it an attractive cleaning technology. Media parameters (size, velocity, and quantity of CO₂ pellets), can be easily adjusted to safely clean a wide spectrum of surfaces and materials ranging from plastic films to steel structures. CO₂ cleaning is also cost effective because liquid CO₂ is readily available and inexpensive. An additional advantage of this technology is the cost savings resulting from the elimination of the secondary waste generation. Existing CO₂ cleaning systems have also developed a vacuum cleaning head that can provide 100% evacuation of all CO₂ gas and debris from the surface while hardware is being cleaned. This technology could be of great use and benefit for application on the TWRS program.

7. BIBLIOGRAPHY

Archibald, K. E., Demmer, R. L., Wendt, K. M., *Alternative Decontamination Technologies*, WINCO, Inc., September 1992.

Capps, Vickie, *Decontamination Investigation Report*.

Evans, M. S., Koehler, D. A., Krieg, S. A., McDaniel, L. B., Mackey, E. L., Manderbach, M. W., MacIsaac, D. J., Wallace, D. A., *Project W-340 Manipulator Retrieval System for Tank 241-C-106*, Westinghouse Hanford Company, WHC-SD-W340-ES-001, August 1993.

Manhardt, Joe, "Decontamination System and Radiation Monitors," TTP ID-432001, January 1994.

Manhardt, Joe, *Preliminary Recommendations and Design Package for a Decontamination System*, INEL, June 1993.

Appendix A

Decontamination Technique Summary Sheets

CO₂ Blasting

This decontamination technique uses liquid CO₂ that is converted into dry ice pellets. The pellets are then propelled at the contaminated object with pressurized gas. When the CO₂ pellet strikes the contaminated object, it sublimates, causing a rapid expansion (pressure spike) of gas at the surface of the object being cleaned. This cleans the unwanted contaminants off the object.

Evaluation criteria	Decontamination method CO ₂ blasting
Removes smearable contaminants	Yes
Removes fixed contaminants	Yes—removes most fixed contaminants
Equipment risk	No
Generates gaseous wastes	Yes
Generates liquid wastes	No
Generates solid wastes	Yes—filters and the contamination removed
Generates mixed WASTES	No
Remote operation	Yes
State of development	Negligible development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities but requires external supply of CO ₂
Simplicity	Simple system to operate and maintain
Preventive maintenance	Yes
Safety	CO ₂ displaces oxygen—need well-ventilated area
Application(s)	Capable of decontaminating all metals, wood, rubber, concrete, plastic, lead, and coated surfaces
Advantages	Compatible with both electrical and mechanical components. Noncorrosive and nonreactive
Disadvantages	Pelletizer unit must be located within 200 ft of the work area. Needs containment for airborne contaminants
Comments	Similar to ice blasting, this method is also known as the dry ice method

Ice Blasting

This decontamination technique uses low-pressure air and ice chips to readily remove radioactive contamination or surface coatings through the process of crack formation and propagation. This process is identical to CO₂ blasting except it uses ice instead of dry ice. It is also known as "wet ice" blasting.

Evaluation criteria	Decontamination method Ice blasting
Removes smearable contaminants	Yes
Removes fixed contaminants	Yes—removes most fixed contaminants
Equipment risk	No
Generates gaseous wastes	No
Generates liquid wastes	Yes
Generates solid wastes	Yes—filters and the contamination removed
Generates mixed wastes	No
Remote operation	Yes
State of development	Moderate development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Simple system to operate and maintain
Preventive maintenance	Yes
Safety	Maximum air pressure will not harm operator; no special handling equipment required
Application (s)	Capable of decontaminating all metals, wood, rubber, concrete, plastic, lead, and coated surfaces
Advantages	Method does not displace oxygen. Once filtered, the spent media (water) can be simply drained away
Disadvantages	Refrigeration unit must be located within 200 ft of the work area. Electrical equipment may require special considerations to keep dry
Comments	Similar to CO ₂ blasting, which is a dry ice method. This method is also known as the wet ice method

Freon

Although Freon has many advantages, its use has been banned by the industrial community due to its negative effect on the Earth's ozone layer.

Evaluation criteria	Decontamination method
	Freon
Removes smearable contaminants	Yes
Removes fixed contaminants	Some
Equipment risk	No
Generates gaseous wastes	Yes
Generates liquid wastes	No
Generates solid wastes	Yes—filters, cartridges, etc., and the contamination removed
Generates mixed wastes	Yes
Remote operation	Remote—in situ, ex situ
State of development	Minimal development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities, but requires external supply of Freon
Simplicity	Moderately difficult to operate and maintain
Preventive maintenance	Yes
Safety	Freon displaces oxygen
Application(s)	Capable of decontaminating all metals, wood, rubber, electrical components
Advantages	Compatible with both electrical and mechanical components. Noncorrosive and nonreactive
Disadvantages	Produces airborne particulate. Banned from industry use
Comments	Industry ban on the use of fluorocarbons

Plastic Beads

Plastic beads or particles are propelled at the contaminated object in a 20 to 80 psi stream of dry air. The beads "wiping" action is adept at removing smearable contamination but is not as effective at removing fixed contaminants. In certain circumstances, the amount of solid secondary waste generated can be minimized by vacuum collection and recycling of the beads; however, oily, dirty, or greasy contamination requires a once-through system (a system in which the beads are not recycled). The beads are certified incinerable.

Evaluation criteria	Decontamination method Plastic beads
Removes smearable contaminants	Yes
Removes fixed contaminants	Some
Equipment risk	No
Generates gaseous wastes	No
Generates liquid wastes	No
Generates solid wastes	Yes—the plastic beads and contamination removed
Generates mixed wastes	No
Remote operation	Yes
State of development	Moderate development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Relatively simple to setup and operate
Preventive maintenance	Yes
Safety	Very little safety concerns
Application(s)	Plastic beads are used to decontaminate objects with little or no fixed contamination in enclosed, controlled area in which recycling can occur. Hand tools used in the nuclear industry are decontaminated using this method
Advantages	Inexpensive and safe
Disadvantages	Not good at removing fixed contamination. Creates solid mixed waste
Comments	Relatively new technique

Hand Wiping

This decontamination process entails the manual wiping or scrubbing by hand or with a power brush, using cleaning/scouring materials and chemical cleaning agents. It is a versatile and inexpensive decontamination process; however workers are directly exposed to the contamination. Also, airborne contamination may be generated, and crevices may be difficult to properly decontaminate.

Evaluation criteria	Decontamination method
	Hand wiping
Removes smearable contaminants	Yes
Removes fixed contaminants	Yes—removes most fixed contaminants
Equipment risk	No—appropriate agents may be selected to prevent damage to equipment
Generates gaseous wastes	Possible—chemical vapors may be produced
Generates liquid wastes	Yes—chemical cleaning agent
Generates solid wastes	Yes—cleaning materials and the contamination removed
Generates mixed wastes	Yes—cleaning agents and cleaning materials
Remote operation	Cannot automate or operate remotely
State of development	Fully developed—cannot be used remotely
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Time consuming and labor intensive
Preventive maintenance	No—none required
Safety	High personnel exposure
Application(s)	Capable of decontaminating all metals, wood, rubber, plastic, lead, and coated surfaces
Advantages	Versatile and inexpensive
Disadvantages	Requires direct worker exposure to contamination. Cannot be automated or remotely operated
Comments	

Hydrolasing

This decontamination technique uses high-pressure water from 1,000 to 20,000 psi to decontaminate the object. Hydrolasing can be performed in situ, ex situ, or remotely. Large volumes of waste water is generated requiring additional processing.

Evaluation criteria	Decontamination method Hydrolasing
Removes smearable contaminants	Yes
Removes fixed contaminants	No
Equipment risk	Yes—potentially destructive to some materials
Generates gaseous wastes	No
Generates liquid wastes	Yes—however the amount of liquid waste may be reduced by recirculating the media
Generates solid wastes	Yes—filters and the contamination removed
Generates mixed wastes	No
Remote operation	Yes
State of development	Minimal development effort necessary for this application
Onsite utilities	Can be operated using "onsite" utilities
Simplicity	Simple system to operate but may be fatiguing if operated manually. May be difficult to maintain because of the wet environment
Preventive maintenance	Yes
Safety	Potential hazards exist to the operator and equipment due to the high pressures
Application(s)	Metals and nonporous materials
Advantages	Once filtered, the spent media, water, can be simply drained away
Disadvantages	Safety operator concerns. Potential for excessive local erosion
Comments	

Strippable Coating

Loose contamination may be removed by using selected strippable coatings. If contamination is not bound to the surface, then "fixing" it using a strippable coating (e.g., latex paint) that is easily removed from the object creates an avenue for decontamination.

Evaluation criteria	Decontamination method Strippable Coating
Removes smearable contaminants	Yes
Removes fixed contaminants	No
Equipment risk	No
Generates gaseous wastes	No
Generates liquid wastes	No
Generates solid wastes	Yes—the coating and the contamination removed
Generates mixed wastes	No
Remote operation	No—requires labor intensive manual operations to apply and remove
State of development	Fully developed—cannot be used remotely
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Since the coatings are applied manually, this method is labor intensive to apply and remove
Preventive maintenance	No—none required
Safety	Extensive exposure of coatings and potentially the contamination to personnel
Application(s)	Virtually unlimited in application to all materials as long as they are not intricate in shape
Advantages	Produces only solid waste. Can be applied by a variety of methods (rolling, spraying, aerosols). Can be used on a variety of surface finishes
Disadvantages	Removed manually, high exposures to personnel. Not recommended for complex geometry. Potential decomposing after extended exposure to radiation
Comments	

Scabbling/Spalling

Scabbling (pummeling that results in chipping) and spalling (breaking off in layers) are proven concrete surface removal techniques. With scabbling, equipment about 2.5 cm of surface can be removed. If deeper contamination exists, spalling methods involving drilling and slicing into the surface can be employed.

Evaluation criteria	Decontamination method Scabbling/Spalling
Removes smearable contaminants	Yes
Removes fixed contaminants	Yes—removes most fixed contaminants
Equipment risk	Yes—significant corrosion of most materials
Generates gaseous wastes	No
Generates liquid wastes	No
Generates solid wastes	Yes—the contamination removed and material removed
Generates mixed wastes	No
Remote operation	No
State of development	Extensive development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Simple system, but extremely labor intensive
Preventive maintenance	Yes—minimal
Safety	Potential hazard to the operator due to flying particles and fatigue
Application(s)	Concrete
Advantages	Low cost
Disadvantages	Only for concrete. Destructive and labor intensive
Comments	Used only for decontaminating concrete; therefore, is not applicable to decontaminating robotic arms. Ventilation required due to airborne particulates

Electropolishing

This technique also known as electrochemical processing, is the opposite of electroplating, but works using the same electrochemical process. The process can be performed in situ or ex situ dependent on the size of the contaminated object. Electropolishing does have some definite limitations. The contaminated objects must be conductive and free of paint, grease, and tape.

Evaluation criteria	Decontamination method Electropolishing
Removes smearable contaminants	Yes
Removes fixed contaminants	Yes—removes most fixed contaminants
Equipment risk	Yes—potential for etching
Generates gaseous wastes	Possible—chemical vapors may be produced
Generates liquid wastes	Yes—high volumes may be reduced by recycling
Generates solid wastes	Yes—spent cathodes, etc., and the contamination removed
Generates mixed wastes	Possible
Remote operation	Remote—in situ, ex situ
State of development	Extensive development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Simple system to operate
Preventive maintenance	Yes
Safety	Safety concerns due to exposure to chemicals and explosion hazard. Potential for Rad exposure if used in situ
Application(s)	Can be used on components of any size. Suitable for stainless steel, mild steels, fuel flasks, pipes, valves, pumps, and tools
Advantages	Short process time
Disadvantages	Accessibility for cathode required. Cannot remove contamination from deep cracks, holes, or shielded areas. Surface must be conductive and free of paint, grease, tape, or surface layers inhibiting conductance. May produce mixed wastes. May cause hydrogen embrittlement
Comments	High volumes of chemical wastes can be generated if recycling system is not implemented recycling presents a potential recontamination problem. Only partially developed for nuclear industry

Vibratory

This decontamination process takes place in a vibrating tub of loose media (ceramic or metal) through which flows a chemical solution or water. The energy from the tub (ultrasonic) causes the media to scrub the surfaces of the object while the liquid flushes away the material being used. The liquid solution used can also be designed to chemically decontaminate. This process is an ex situ process and may require the cutting up of the object to fit into the tank prior to decontamination.

Evaluation criteria	Decontamination method Vibratory
Removes smearable contaminants	Yes—on hard materials only. On soft materials the contamination becomes impregnated
Removes fixed contaminants	Yes—on hard materials only. On soft materials the contamination becomes impregnated
Equipment risk	Yes—parts may need to be cut up to fit into vibratory tanks. Vibration may damage robotics
Generates gaseous wastes	Possible—chemical vapors may be produced
Generates liquid wastes	Yes—liquid can be recycled but filters are easily plugged, and a greater probability of recontamination occurs as compared to a single pass system
Generates solid wastes	Yes—filters, grit, etc., and the contamination removed
Generates mixed wastes	No
Remote operation	Remote—ex situ only
State of development	Extensive development effort necessary for this application
Onsite utilities	The system can operate using "onsite" utilities
Simplicity	Time-consuming and requires care and attention to process control
Preventive maintenance	Yes
Safety	Low personnel radiation exposure levels
Application(s)	Stainless steel, CSTL, glass, rubber, plastics
Advantages	Usually produces good decontamination factors
Disadvantages	Batch process that is relatively time-consuming. Limited to hard materials. Potential recontamination problems. Requires cutting materials to length. Potential corrosion and erosion problems. Unsuitable for close toleranced parts
Comments	

Chemical Washing

The decontamination of equipment using chemical washing is one of the most applied decontamination techniques. Chemical washing offers the potential of surface contamination removal from the interior and exterior of equipment, cracks, and porous materials. However, chemical washing has lost favor, primarily because chemicals are closely regulated, the resulting decontamination waste presents disposal difficulties, and an increased waste volume occurs.

Evaluation criteria	Decontamination method Chemical Washing
Removes smearable contaminants	Yes
Removes fixed contaminants	No (Yes—if using acids)
Equipment risk	Yes—potentially destructive if using acids
Generates gaseous wastes	Possible—chemical vapors may be produced
Generates liquid wastes	Yes
Generates solid wastes	Yes—grit, filters, precoat, etc., and the contamination removed
Generates mixed wastes	Possible—if using acids
Remote operation	Remote—ex situ only
State of development	Extensive development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	System is simple to operate, however, requires extreme caution while handling the chemicals
Preventive maintenance	Yes—minimal
Safety	Use of acids pose safety concerns
Application(s)	Stainless steel, CSTL, glass, some plastics
Advantages	Short application times. Good for stainless steel
Disadvantages	Large chemical inventories required. Can be corrosive for some metals. Components must be cut to length to fit into the tanks
Comments	The generation and disposal of generated wastes pose considerable concerns. Recycling the chemicals is an option but presents a potential recontamination problem

Steam Jet

This decontamination method uses high pressure steam to remove surface contamination. The same general surface conditions as hydrolasing are involved.

Evaluation criteria	Decontamination method Steam Jet
Removes smearable contaminants	Yes
Removes fixed contaminants	No
Equipment risk	Yes—high temperatures may damage sensitive equipment
Generates gaseous wastes	No
Generates liquid wastes	Yes
Generates solid wastes	Yes—filters and the contamination removed from the tank
Generates mixed wastes	No
Remote operation	Remote—in situ, ex situ
State of development	Minimal development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Maybe difficult to operate (nozzle needs to be 6 to 9 in. from the object) and maintain
Preventive maintenance	Yes
Safety	Potential danger to operator and equipment due to high pressures and temperatures
Application(s)	Metals and other nonporous materials
Advantages	Steam jet cleaning has the advantage of thermal shock (immediate local material expansion or contraction) to assist in the decontamination process
Disadvantages	Disadvantages are the safety concerns of working with high temperatures, high pressures, and large volumes of liquid waste
Comments	Compared to hydrolasing, the waste volume generation is generally lower

Light Ablation

This decontamination process utilizes light pulses to heat a contaminated surface film to 1,000 to 2000°C in microseconds. This process decontaminates a substrate in three ways: by sublimating or vaporizing the contaminate, by ablation or thermal shock, and by the scouring effect which the produced vapors have on other particles. Flashlamps or lasers are used to produce the high energy pulses of light. While experimental systems are effective at removing contaminated films and coatings, light ablation is not effective at removing larger particles of waste.

Evaluation criteria	Decontamination method Light Ablation
Removes smearable contaminants	Yes
Removes fixed contaminants	No
Equipment risk	Possible—some materials may be damaged by the energy necessary to remove contamination
Generates gaseous wastes	Yes
Generates liquid wastes	No
Generates solid wastes	Negligible—particulate emissions would be collected by the ventilation system
Generates mixed wastes	No
Remote operation	Yes
State of development	Extensive development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	System difficult to setup, but simple to operate
Preventive maintenance	Yes
Safety	High heat produced may present an explosion hazard
Application(s)	Capable of removing films and coatings from a wide variety of surfaces with little damage to the substrate
Advantages	Very little secondary waste is produced
Disadvantages	Expensive and ineffective at removing large particles of waste
Comments	Ventilation system may be necessary for vapors and airborne particulates produced

Abrasion (Grit Blasting)

Abrasion or grit blasting is an effective decontamination method in which an insoluble abrasive is propelled by a jet of air (dry blasting) or water (wet blasting) at the contaminated object. Typical abrasives are, for example, sand, alumina, metals, and metal oxides. Sand is the most common abrasive because it is inexpensive and a good scouring agent. Wet blasting is more effective than dry blasting in cleaning crevices and in reducing the amount of airborne contamination. For both methods, a final rinse is usually required after cleaning to ensure that the surface is free of abrasive.

Evaluation criteria	Decontamination method
	Abrasion (Grit Blasting)
Removes smearable contaminants	Yes
Removes fixed contaminants	Some
Equipment risk	Yes—excessive local erosion possible
Generates gaseous wastes	No
Generates liquid wastes	Yes—if wet blasting
Generates solid wastes	Yes—grit, filters, precoat, etc., and the contamination removed
Generates mixed wastes	Possible
Remote operation	Yes
State of development	Moderate development effort necessary for this application
Onsite utilities	System can operate using "onsite" utilities
Simplicity	Relatively simple to setup and operate
Preventive maintenance	Yes
Safety	Potential danger to operator and equipment if proper precautions are not taken
Application(s)	Abrasive blasting can be used on large cell applications or in enclosed glovebox-type units. Generally, applications are limited to the decontamination of metals as recontamination/erosion occurs with softer or porous materials. Operations can be performed either wet or dry
Advantages	Variety of abrasives can be used
Disadvantages	Abrasives can become imbedded in the substrate. Requires close supervision. Potential difficulties in balancing feed of abrasive
Comments	Ventilation required due to airborne particulates

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