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Decontamination Techniques and Fixative Coatings Evaluated in the Building 235-F Legacy Source Term Removal Study

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Introduction

Savannah River Site Building 235-F was being considered for future plutonium storage and stabilization missions but the Defense Nuclear Facilities Safety Board (DNFSB) noted that large quantities of Plutonium-238 left in cells and gloveboxes from previous operations posed a potential hazard to both the existing and future workforce. This material resulted from the manufacture of Pu-238 heat sources used by the NASA space program to generate electricity for deep space exploration satellites. A multi-disciplinary team was assembled to propose a cost-effective solution to mitigate this legacy source term which would facilitate future DOE plutonium storage activities in 235-F. One aspect of this study involved an evaluation of commercially available radiological decontamination techniques to remove the legacy Pu-238 and fixative coatings that could stabilize any residual Pu-238 following decontamination activities. Four chemical methods were identified as most likely to meet decontamination objectives for this project and are discussed in detail. Short and long term fixatives will be reviewed with particular attention to the potential radiation damage caused by Pu-238, which has a high specific activity and would be expected to cause significant radiation damage to any coating applied. Encapsulants that were considered to mitigate the legacy Pu-238 will also be reviewed.

Decontamination Methods

Various radiological decontamination methodologies have been investigated to support removal of plutonium-238 legacy contamination from cells and glove boxes located in Building 235-F. Four chemical decontamination methods have been identified as the most likely to meet the decontamination objectives for this project. These chemical methods include nitric acid, cerium nitrate, Gylgel (cerium nitrate gel) and the RadPro® decontamination process. Three of these four methods have been evaluated in DOE Innovative Technology Reports (nitric acid, cerium nitrate, and RadPro®). Glygel is a delivery system for cerium nitrate, so its performance is assumed to be similar to that described in the DOE report for cerium nitrate.

Discussion

Two different evaluations compared nitric acid as the baseline decontamination technology to cerium nitrate [1] and the RadPro® process [2]. All of these methods required manual application of the decontamination chemicals by spraying the solution inside the glovebox and then scrubbing the chemical into the surface material. The chemical would be left on the surface for at least twenty minutes before being removed by a rinsate solution and wiped down with rags. The

RadPro® process differed in that it required three different chemical formulations to be applied (and removed) to constitute a single decontamination cycle.

The cerium nitrate comparison found that nitric acid outperformed cerium nitrate during the initial decontamination cycle [Decontamination Factor (DF) of 12.3 versus 7.9 for cerium nitrate. The DF is derived by dividing the initial contamination value by the final value decontaminated]. However, the nitric acid DFs were lower than those for cerium nitrate during decontamination cycles, which resulted in slightly better results for the cerium nitrate method after 5 cycles. The report offered no explanation as to why cerium nitrate, which was the more aggressive chemical, did not perform substantially better than the nitric acid during the initial decontamination cycle.

The second DOE report compared the RadPro® decontamination process to the baseline nitric acid technique. The RadPro® DF of 25 following a single cycle was impressive, but follow-uo decon cycles only yielded an average DF of 1.4. The nitric acid method results were not consistent with the cerium nitrate evaluation as DFs of 2.3 were observed for several decontamination cycles. Comparison od DFs for cerium nitrate versus RadPro® revealed that after three decontamination cycles, the DF for RadPro® was 50 and only 20 for cerium nitrate. However, several additional cerium nitrate decontamination cycles would result in both methods achieving similar DFs.

The Gygel technology has been used for commercial nuclear applications and a DF of 10-50 is claimed by the vendor. This technology employs cerium nitrate in a gel form that can be brushed or sprayed on contaminated surfaces. The gel is a bright orange color when first applied which turns to white once the cerium reacts with the plutonium, which usually takes three hours. The spent gel, which is chemically inert, can then be vacuumed off the surface after it dries (24 hours after application).

The two most promising decontamination methods for Building 235-F applications are discussed in greater detail below.

RadPro® Decontamination Process

The RadPro® Decontamination process has been used at several DOE sites for removal of Pu-239 from gloveboxes and could be used for the same purpose in Building 235-F as the chemistry is the same for Pu-238. This process has been shown to exhibit higher initial decontamination factors than several competing technologies in DOE Innovative Technology Summary Reports.

The RadPro® process employs up to 25 different components applied in three sequenced chemical formulations to extract radiological contaminants. The first two applications are surface preparation formulas with the third formula used to penetrate below the metal surface and chemically bind to the contaminants. The RadPro® chemicals contain no hazardous components regarding flammability or reactivity and result in a neutral pH (7) at disposal.

RadPro® chemicals are applied as an atomized spray to minimize generation of secondary waste. After being applied, the chemicals are scrubbed into the contaminated surface, left for a period of time (typically 30 minutes), and rinsed and removed by wiping with a cloth (vacuuming is also possible for large scale operations). Typical liquid waste volumes generated range from 0.04 to 0.10 gallons per square foot for an entire project. The application and removal of all three formulas constitutes one cycle of the process, and usually requires 24 hours. Decontamination factors of up to 25 can be achieved for the first decontamination cycle (i.e., over 90% of the initial activity is removed).

An additional benefit of employing the RadPro® process is that it may be capable of decontaminating Building 235-F gloveboxes from TRU waste levels to Low Level Waste.

Cerium Nitrate Gel

Cerium nitrate is capable of reacting with and solubilizing plutonium and stainless steel components such as nickel, chronium and iron. The cerium nitrate gel is sprayed onto surafces and chemically strips a very thin layer from the surface of the glovebox which results in removal of fixed contamination in the oxide layer of the metal.

The cerium nitrate gel formulation (Glygel) offers significant advantages for the Building 235-F decontamination effort over liquid decontamination methods (cerium nitrate solution or the RadPro process) as follows:

- Viscosity of gel allows for an easy application onto vertical walls and ceilings (no dripping)
- No labor intensive scrubbing application or manual wipedown removal operations are required (the gel can be brushed or sprayed onto metal surfaces and removed by vacuuming)
- The vendor claims that decontamination goals are usually achieved after 1 or 2 gel applications
- No liquid or hazardous waste generated (the dried gel is chemically inert).

The Glygel formulation is thrixotropic, meaning it liquifies when shaken or stirred which allows the gel to be sprayed on a surface. The gel is mixed just before application as the cerium oxidizes the organic constituent of the gel which dries on a surface. The gel is mixed just before application as the cerium oxidizes the organic constituent of the gel which dries into crystals after several hours. The gel turns from an orange to white color upon oxidation and can be vacuumed off the surafce when it dries. All surfaces to be decontaminated must be free of grease and oils and the Glygel formulation will not damage transparent surfaces (Lexan, glass, Plexiglass, etc). The decontamination factor of Glygel has been reported to be the same as that for cerium nitrate in solution. On average, 500-1000 grams of Glygel are used to decontaminate an area of one square meter.

Operational Issues

Two problems were identified in both DOE reports that are applicable to the Building 235-F Legacy Source Term removal Project for all decontamination techniques except the Glygel method. The first is the ability to physically reach all interior surfaces of a glovebox. The DOE reports recommended that further experimentation to perfect mechanical means (extension sticks, grippers, etc) of reaching all interior surfaces with enough leverage to apply scrubbing force. The second issue identified that the decontamination cycle iterations required chemical application, scrubbing, rinsing and wipedowns are very labor intensive and fatiguing.

Waste Minimization and Disposal

The decontamination technology evaluation found that the use of cerium nitrate versus the baseline technology (nitric acid) did not reduce the overall waste generated on a per cycle basis. However, the RadPro® process resulted in a waste savings factor of approximately 20 as compared to the nitric acid method. The Glygel method results in a solid waste being generated for disposal, which is preferable to the wet decontamination methods. The waste stream for both methods must be evaluated for any disposal issues that would preclude their shipment to WIPP.

Decontamination Recommendations

The decontamination methods reviewed for this study are summarized in Table 1. For glovebox decontamination in which accessibility is not a major issue, the RadPro® process offers the best initial decontamination results. However, cerium nitrate also offers acceptable decontamination factors when the goal is non-Low level waste status, as is the case for this project. The Glygel process appears to be a good method for Building 235-F glovebox and cell decontamination as it can be remotely sprayed on and vacuumed. Determining the best of these decontamination methods should be validated under field conditions.

TABLE 1

Decontamination Methods

Name	Description	Pros	Cons
RadPro® Decontamination Process Supplier: Environmental Alternatives, Inc.	This decontamination process employs 3 different chemical formulations to extract contaminants from metals.	1. Has a high initial decontamination factor. 2. Reduces amount of radwaste generated when compared to other liquid decontamination agents. 3. Decontamination method of choice to reach LLW status for gloveboxes. 4. Results on non-hazardous wate being generated.	1. Labor intensive and requires three different chemical formulations applied to constitute a single decontamination cycle. 2. Results in low volumes of liquid waste being generated.
Gylgel Supplier: STMI	This decontamination process is a cerium nitrate gel that is brushed or spayed directly on surface to be decontaminated. After the gel oxidizes (changing from an orange to white color) and dries, it can be vacuumed up.	1. Can be remotely applied and removed (not labor intensive). 2. No liquid or hazardous waste generated. 3. Similar decontamnation factors to the RadPro® process (for more than one decon cycle).	1. Must handle hazardous chemical before it is mixed into gel form. 2. Needs to be tested for glovebox decontamination applications.
Cerium Nitrate Supplier: Chemical Supplier (non-proprietary)	Chemical decontamination solution is sprayed onto the surface and then scrubbed into the surface. The addition of cerium to nitric acid results in a more aggressive chemical decontamination process.	1. Similar decontamination results to RadPro® process (for more than one decon cycle). 2. Chemical solution is non-propietary.	1. Chemical very hazardous to handle. 2.No appreciable reduction in radwaste generation over baseline decontamination technology (nitric acid). 3. Labor intensive to apply.
Nitric Acid	This decontamination method consists of spraying nitric acid	1. Baseline technology for DOE studies.	1. Most labor intensive method 2. Lower overall

	(0.5 normal) onto a surface, scrubbing the solution into the surface and then wiping it off after 20 minutes.	2. Low cost	decontamination factor than other methods 3. Creates largest amount of contaminated waste. 4. Chemically hazardous to handle.

Fixation Methods

For this study, the term fixative may be used for two purposes: 1) Short-term - coatings that will fix contamination on surfaces while work is ongoing and until the items are packaged for waste disposal; and 2) Long-term - coatings that will fix contamination for periods of time up to twenty years or longer.

The short-term fixatives were evaluated based on expected performance, ease of use, and waste disposal acceptance. Long-term fixatives were evaluated based on performance, radiation resistance, and long-term surface adherence. The following discussion includes only those fixatives identified as best suited for use in this project. Table 2 includes a general description of the fixatives evaluated. Other fixatives not listed may have been considered, but were eliminated due to obvious short-comings.

Short-Term Fixatives

The function of short-term fixatives is to reduce the risk of material release during work activities. Coated items will be disposed as waste and sent to waste disposal. The coatings are intended to remain functional only until packaged for disposal.

The following fixative coatings are suitable for short durations:

- Aerosol Capture Coatings
- Strippable Coatings
- Polymeric Barrier System

<u>Aerosol Capture Coating</u>

Aerosol capture coating, or fogging, is a method of reducing airborne contamination and temporarily fixing contamination. An aerosol generator creates an aerosol, similar to “fog”, of organic material that is slowly introduced into an enclosed area (such as a room, glove box, ventilation duct, etc.). The aerosol is pumped from the aerosol generator through ducts to the enclosed area. No personnel or equipment is required to enter the area being treated. This aerosol encapsulates contamination and prevents resuspension of contaminants by coating all surfaces within the area. The coating material adheres to the surface being coated and the resulting layer is tacky in consistency. This tacky coating encapsulates any fine loose surface material located in the process area. The thickness of the applied coating varies based on the type of coating used and the number of coats applied. The thickness of one application is typically 3 to 5 mils.

The capture coating will not dry to a durable coating or permanently fix contamination. The contamination may be dislodged by work activities. If a more durable surface is needed during work activities, other water based fixatives can be applied over the capture coating.

SRS has successfully used aerosol fogging produced by Encapsulation Technologies, LLC.

Strippable Coatings

Strippable coatings are simple effective means of removing or preventing the spread of contamination. Strippable coatings are usually water based coatings that are applied by spraying, rolling, or brushing in the same manner as paint. A heavy duty commercial airless paint sprayer is required for spraying. Coatings usually require 24 hours to completely dry. After drying, strippable coatings are durable and can withstand reasonable wear. The coatings are not hard, but flexible.

When used as a decontamination agent, strippable coatings are applied over contaminated surfaces. After drying, the coatings are stripped away from the surface with contamination encapsulated in the coating. If used to fix contamination and prevent spreading, surfaces are covered with strippable coatings and the coatings left in place. A second coating can be applied after working in an area to fix additional contamination spread to surfaces by work activities.

Stripcoat TLC (supplied by Bartlett Services, Inc.) and ALARA 1146 (supplied by Sherwin Williams) are dependable coatings. Both have been successfully used at SRS.

Polymeric Barrier System (PBS)

The PBS, provided by Bartlett Services, Inc, is a coating developed to form a strong impermeable barrier between hazardous materials and the environment. The acrylic-like single component system can be applied in any thickness by applying multiple coatings. This feature permits crevices, small openings, irregular surfaces, etc., to be enclosed by the coating. Loose solids can be mixed with the coating to encapsulate loose materials. The PBS can be applied on most surfaces to include soils, metals, concrete, plastics, and painted surfaces.

The PBS is applied with rollers, brushed, or sprayed with an airless sprayer or garden sprayer.

Table 2 Fixative Materials

Name	Description	Advantages	Disadvantages
Aerosol Capture Coating (Fogging) Supplier: Encapsulation Technologies	Aerosol created from liquid material is pumped into enclosed area. Aerosol deposits as a sticky film on all surfaces. Airborne and loose contamination is captured in coating. The nominal thickness of the coating is 3-5 mils.	1. Does not require physical entry into contaminated area - aerosol pumped into area thru opening 2. Reduces airborne contamination and temporarily fixes smearable contamination 3. Aerosol reaches hard to access areas 4. Can be coated with a water based coating such as strippable coatings or PBS if a more durable coating is required	1. Coating does not dry to durable condition. The captured contamination can be loosened by rubbing or disturbing coating. 2. Not durable for holding contamination during work activities
Strippable Coatings Supplier: Bartlett Services (Stripcoat TLC) or Sherwin Williams (Alara 1146)	Removable coating applied by spraying, brushing, or rolling. When dry, the pliable coating can be either left in place to provide a durable coating that fixes surface contamination or peeled away to remove contamination.	1. Durable – can withstand reasonable wear 2. Can be left in place to provide contamination control while other work in glovebox is ongoing 3. A second coat can be applied to fix contamination released during work activities.	1. Would require several coats to cover equipment, wiring, etc. 2. All glovebox inside surfaces may not be accessible to spray using only glove port access
Polymeric Barrier System (PBS) Supplier: Bartlett Services	PBS is a non-toxic, water-based coating that provides a strong impermeable barrier to control migration of hazardous materials. The single component coating can be applied with airless spray equipment or garden sprayer. Remains pliable after drying.	1. Can be applied in any thickness by applying multiple layers 2. Can be mixed with loose solids to encapsulate hazardous materials 3. Can be applied with garden sprayer 4. Can be applied to a variety of surfaces: soils, metal,	1. No history of long term radiation effects 2. Organic material

		concrete, paper, plastics, painted surfaces	
InstaCote®-ML Supplier: Master-Lee	Two part polyurea coating applied with spray system. Provides solid durable coating that can encapsulate and seal contaminants.	1. Can be applied in any thickness 2. Very durable 3. Hardens in seconds 4. Permanent 5. Fire resistant formulas available	1. Requires special commercial equipment for application
NoDAC Supplier: Bartlett Services	Polyvinyl acetate based, non-toxic designed for the control of contamination during maintenance activities. It can be applied by brush, roller, spray bottle, garden sprayer, or paint sprayer.	1. Hard durable coating 2. Does not require commercial spray equipment 3. Can be applied over damp, wet surfaces 4. Fast cure – 15 to 30 minutes	1. Easily dissolves in water after drying. 2. All inside glovebox surfaces may not be accessible using only glove port access
Foam – Dow Froth Pak Supplier: Dow Chemical	Two part light weight polyurethane foam applied by spray	1. Good coverage of irregular shapes, voids, and crevices 2. Simple, cheap spray equipment	1. Will not support flame but decomposes under direct flame
FireDam™ Spray 100 Supplier: 3M	Sprayable water-based coating that dries to a elastomeric coating. Developed to seal construction joints against fire, heat, and smoke.	1. Non-flammable – designed to withstand fire and heat one time, not repeated fire and heat cycles. 2. Covers crevices and small voids 3. Applied with commercial spray equipment	1. Adherence to substrate over long period of time is unknown. 2. Resistance radiation is unknown 3. All surfaces may not be accessible to spray using only glove port access

Long-Term Fixatives

A fixative is applied to a radiologically contaminated surface to prevent or mitigate a release. Prior to making a decision to apply a fixative or the selection of a fixative, several items must be addressed. These include: (1) the mechanism for release; (2) the intended duration over which the fixative must perform its intended function; and (3) the cost of the fixative, including application and maintenance, relative to other alternatives (e.g., application of a fixative vs. decontamination). In addition, application of a long-term fixative should only be considered when future decontamination is not anticipated. If future decontamination may be required, selection of the fixative must consider its ability to be removed in a cost effective manner. It must be cautioned that this may impact the ability of the fixative to perform its intended function over the required duration, therefore, increasing maintenance costs and worker risk.

With respect to the first item, mechanism for release of contamination, it is assumed for this study that the mechanism for release is failure of a primary confinement barrier as a result of normal aging. For example, a glovebox window seal may fail as a result of the material becoming brittle and cracking. In this case the fixative then becomes the primary confinement barrier. Under this assumption, the fixative does not have to withstand the effects of an external force such as fire.

In this study, the duration over which any fixative must be able to perform its intended function has been established as a minimum of 20 years. This is a relatively long time period for most "long-term" fixatives. In fact, many of the newer fixatives have not even been on the market, therefore, not in use, for this period of time. As a result, their ability to perform the intended function over this duration can only be postulated. With many of the fixatives their normal use is in a nonradiological environment. Use as a fixative may shorten the expected material life as a result of the effects of radiation exposure. This is of particular concern for application with Pu-238. Radiation exposure causes two primary concerns with exposure to Pu-238. The first is material damage resulting from radiation interaction with the material and the second is the heat generated from decay of Pu-238. Most of the fixatives available are organic materials which tend to be more susceptible to radiation damage. The alpha particles emitted by Pu-238 have a range of only a few mils in typical fixatives. This is a significant concern since all the decay energy will be deposited in a thin layer at the interface of the contaminated surface and the fixative. Damage in this area may cause the fixative to break loose from the surface. This loss of effectiveness would not be expected to be catastrophic. It should be considered to be analogous to paint peeling from the outside of a house. There will be some loss of effectiveness as damage becomes severe, but will be spotty and increase over time. Little is known about the dose/damage relationship for specific fixatives. However, materials similar to most of the fixatives have been reported to undergo moderate to sever damage when exposed to doses of gamma radiation in the range of 10^6-10^8 rad. Assuming a Pu-238 surface contamination level of 10^6 dpm/100cm^2, damage may be expected to occur in typical fixatives in 18 to 1800 years. For Pu-238 the relationship between time to damage and contamination level should be conservatively considered to be inversely proportional to contamination levels of up to about 10^{12} dpm/100cm^2. Above this level additional activity will have no effect on material life as a result of self-shielding by the Pu-238. For example, a contamination level of 10^7 dpm/100cm^2 would result in material damage occurring in 1.8-180 years. Following decontamination, acceptable contamination levels would not generally be expected to be above 10^7 dpm/100cm^2. It should be noted that InstaCote®ML has been reported to undergo significant damage at 2E8 rad putting it in the upper end of the dose range and making it a good choice as a fixative from a radiation damage standpoint. Also, grout is a very radiation tolerant material and radiation damage should not be of concern in this application. Damage from a heating standpoint in this application for any of the materials is not expected to be of concern since the heat loading for Pu-238 in the 10^6-10^7 dpm/100cm^2 range would only be about 10^{-10}-10^{-9} W/cm^2. Obviously, the heat loading would be much greater where accumulations of Pu-238 exist. In this case the loading would be about 0.57 W/gm-Pu238.

The third item to be considered prior to the decision to apply a long-term fixative or selection of a long-term fixative is the relative cost, and benefit, for the fixative compared to other alternatives (e.g., decontamination). An important point to be considered is the life of the fixative. In order to maximize the life (i.e., adherence to the surface) the surface must be prepared prior to application. As a result, some decontamination must be performed to prepare the surface prior to applying the fixative. The decision then becomes one of balancing the cost of additional decontamination, along with the associated waste disposal costs and risk, with the cost of applying a long-term fixative, along with its associated maintenance costs and risks.

The following coatings have potential as long-term fixatives:

- InstaCote®-ML
- Epoxy Coatings
- FireDamTM Spray 100

InstaCote®-ML

InstaCote®-ML is a two-part polyurea plastic coating that is used as a permanent surface coating. The coating is applied using a special spray system that heats and mixes the components. The material leaving the spray gun is a gel-like solid that hardens to the touch in seconds. The coating completely cures to a flexible solid within 18 – 24 hours. The final coating thickness can be increased by applying multiple coats to cover crevices, openings, irregularly shaped items, etc. The cured coating is very durable and will withstand physical wear and severe environmental conditions. (A common commercial use for InstaCote®-ML is the bed lining for trucks.)

Gamma radiation tests were performed on samples of InstaCote®-ML by the manufacturer. Samples were exposed to 2.0E08 rads. Tensile strength and elongation had significantly deteriorated at that dose.

InstaCote®-ML is furnished by Master-Lee and has been successfully used at SRS as a coating to seal contaminated surfaces.

Epoxy Coatings

Epoxy coatings with high solids content can be used to fix surface contamination. The high solids epoxies can be applied in thick coats by applying multiple coats to bridge small crevices and irregular shapes. Epoxies offer better surface adhesion than most coatings, but require some surface preparation prior to application. The better the surface preparation, the better the coating will adhere over the long time period. There are several epoxy formulations that can be selected based on environmental and surface conditions. Epoxies may also have high solvent content that require precautions during applications.

FireDam™ Spray 100

The FireDam™ Spray 100 was originally designed as a firestop for building joints. The material will control the transmission of fire, smoke, and heat during and after exposure to fire. The coating is designed to withstand a one-time exposure to fire and heat, but not repeated cycles of heat and fire. FireDam™ Spray is a water-based material that dries to form an elastic coating. It is applied with commercial spray equipment over clean, dry, dust-free surfaces.

Fixative Recommendations

For short term fixatives, the aerosol capture coating is recommended prior to the start of work activities in the glovebox or cell. This will reduce airborne contamination and fix surface contamination. Additional applications may be needed if airborne contamination is created during work activities. If a more durable coating is needed, a coating of PBS or strippable coating can be applied over the capture coating.

The aerosol capture coating is recommended because it can be applied without physical entry into the gloveboxes or cells. By applying the coating prior to entry, the potential for contamination release is greatly reduced. The aerosol is easy to apply into the cell using a portable fogging machine approximately 3 ft W x 4 ft L x 4 ft H. The aerosol can be pumped up to 150 ft using flexible duct. Once applied, the coating does not interfere with the decontamination and fixation tasks. Most water soluble coatings can be applied over the aerosol coating after it has dried. The PBS coating does not require special application equipment and can be applied with a garden sprayer (no lines running into the cell) or strippable coatings can be applied with commercial type airless sprayers.

The first choice for a long-term fixative is the InstaCote®-ML. InstaCote®-ML has good adhesion properties and with reasonable surface preparation, the coating should last for several years. A strippable version of InstaCote®-ML can be applied to the outside of gloveboxes, either over the entire surface or, as a minimum, at bolted connections and penetrations. This outside coating can be removed to allow access to glovebox joints during final disposition.

Although InstaCote®-ML contains organic materials, it's resistance to alpha radiation is expected to be acceptable if decontamination results are as expected. It is recommended as a long-term fixative over the other materials because of its adhesion properties. Experience at SRS indicates that it does adhere to surfaces over long periods with a minimum surface preparation.

Epoxy coatings may have better radiation resistance, but require very good surface preparation to achieve surface adhesion to stainless steel. Surface profiling (grit blasting) and a primer coat are essential surface preparation steps.

No fixative coating is expected to adhere for long periods without some failure. The use of any of these fixatives will require periodic surveillance to confirm condition and surface adherence. Maintenance and repair of the coatings may be required depending on initial surface condition and the length of time before final disposal.

Encapsulation Methods

Encapsulation materials are used to incorporate or stabilize contamination for long-term storage. The main characteristic of an encapsulate is that it be stable for a long period of time. For stabilization of Pu-238, the resistance to alpha radiation and heat is a prime concern.

For this project, encapsulation is a stabilization method to reduce potential for release of radioactive materials until final disposition of the facilities. The safety analysis for the project end-state will determine acceptability of the encapsulation method.

Table 3 below lists the encapsulation materials evaluated for use in 235-F. The recommended encapsulates are discussed. Other materials not listed may have been considered, but were eliminated due to obvious short-comings.

Table 3 Encapsulation Materials

Name	Description	Advantages	Disadvantages
Low Density Grout (Celcore Cellular GeoFill) Supplier: Celcore Inc.	Portland cement and foam mixture that hardens like grout but is light weight	1. Performs same as grout but light weight 2. Grout/foam ratio can be varied to produce varying densities 3. Reduces additional structural support	1. Leaving cells or gloveboxes grouted in place for later disposal limits future disposal options.
EKOR Sealer Product Supplier: Eurotech, Ltd.	Single component silicon/geopolymer that can be applied by spraying, pouring, or brushing. Can be used as a solid sealer or encapsulate. Radioactive material can be mixed with EKOR for encapsulation.	1. Silicon based material (non-organic) 2. Manufacturer's tests and data show material is highly resistant to radiation, aging, and weathering 3. Does not burn or support burning 4. Used at Chernoybl	1. No history of use in U.S. Demonstrations only 2. Use as a sealer in a demo at SRS showed problems with adherence to stainless steel surfaces
Epoxy Coatings Epo-Flex Supplier: General Polymers	High solids content epoxy coatings	1. Many formulations available for different surface conditions 2. High solids content allow application of thicker coatings than normal epoxies	1. May have high solvent content causing problems with application in facility 2. May require multiple coats for complete coverage of cell and equipment 3. Requires surface preparation for good adherence to stainless steel 4. No history of long term radiation effects 5. All surfaces may not be accessible to spray using only glove port access
Polymeric Barrier System (PBS) Supplier: Bartlett Services	Acrylic like coating applied with airless sprayer or garden sprayer. Remains pliable after drying.	1. Can be applied in any thickness by applying multiple layers 2. Encapsulates loose solid materials	1. No history of long term radiation effects 2. Possible organics

InstaCote®-ML Supplier: Master-Lee	Two part polyurea coating applied with spray system. Provides solid durable coating that can encapsulate and seal contaminants.	1. Can be applied in any thickness 2. Very durable 3. Hardens in seconds 4. Permanent or strippable 5. Fire resistant formula available	1. Organic components 2. No history of long term alpha radiation effects
Enviro Seal Supplier: Encapsulation Technologies	Two part epoxy with varying cure times. Usually applied by pouring.	1. Moisture does not affect curing 2. Could individually encapsulate small amounts of materials	1. Organic components 2. No history of radiation effects 3. Cannot be applied by spraying
FireDam™ Spray 100 Supplier: 3M	Sprayable water-based coating that dries to an elastic coating. Developed to seal construction joints against fire, heat, and smoke.	1. Non-flammable 2. Covers crevices and small voids 3. Applied with commercial spray equipment	1. Contains organics 2. No history of radiation effects 3. All surfaces may not be accessible to spray using only glove port access

Note: Costs do not include application equipment.

The materials with potential for encapsulation are:

- Celcore Lightweight Insulating Concrete
- EKOR™ Sealer
- InstaCote®-ML

Celcore Lightweight Insulating Concrete

Concrete grout is a proven method for stabilizing radioactive materials. It has been used to stabilize radioactive isotopes in the Old F-Area Seepage Basin and in F-Area waste tanks. As an encapsulate in OML, PEF, or PuFF, use of regular grout or cement in the gloveboxes or cells would require additional support to the filled structures.

The Celcore lightweight concrete was developed for use as a concrete roofing material. Its lightweight reduces additional structural supports required when using regular concrete. Foam, created in a foam generator from liquid surfactant, replaces sand and gravel in the normal Portland concrete mixture. By varying the foam to cement ratio, the density of the cement can be varied.

Celcore has been used at SRS and other DOE sites as a grout for encapsulating radioactive materials.

For proper performance, the grout must be formulated depending on project objectives. Accumulated amounts of Pu-238 containing materials can be removed or mixed with the encapsulate materials to form a matrix. Accumulated materials “sandwiched” between the grout and cell liner may be dispersed if the cell liner is breeched during an accident or during future size reduction. Another option is to enclose the cell liner in concrete or grout as a macroencapsulation method. Whatever option is chosen, the grouting method must meet the stabilization needs required by the safety analysis of proposed end-state.

EKOR™ Sealer

EKOR™ is a silicon-based material originally designed as a highly radiation-resistant material. EKOR™ can be used as a coating or an encapsulate for assorted dry wastes. EKOR™ can be applied by spraying, pouring, brushing, or rolling. Vendor testing indicates high resistance to gamma radiation (10 Gigarad), aging, and heat. EKOR™ is available either as a two component that requires mixing prior to application or as a pre-mixed material ready for application.

EKOR™ was demonstrated at SRS on two occasions. One was a demonstration of its general use as a coating on steel and concrete and as an encapsulate for solids (i.e., dirt, ash, metal shavings, etc.). The demonstration was considered successful. The other was a demonstration as a coating and encapsulate for materials in a concrete sump. There was a problem with adherence to the surface of the concrete in the second demonstration. Some of the coating did not adhere to stainless steel surfaces.

EKOR™ has been used to encapsulate radioactive materials at Chernobyl. It has been demonstrated on several occasions, but otherwise has limited use in the United States.

InstaCote®-ML

InstaCote®-ML materials as described in Section 4.4.2 have physical characteristics of a good encapsulate; however, accumulated materials are not easily mixed with the InstaCote®-ML during application. The InstaCote®-ML material hardens too quickly to allow mixing.

Epoxy Coatings

Epoxy coatings as described in the long-term fixatives section may also be used as an encapsulation material if contamination is present only as surface contamination. The epoxy coating alone will not encapsulate appreciable amounts of solids. The high solid content epoxy coatings should not be affected by low levels of alpha radiation, but further evaluation and tests will be required before use as an encapsulate.

A potential problem with epoxy coatings is the surface preparation required to assure proper adherence to the substrate. As with all paint products, good surface preparation and primer are required to assure the best long-term adherence.

Encapsulation Recommendations

The use of grout is recommended as an encapsulate material because of its proven performance in stabilizing radioactive materials. The low density Celcore will reduce the additional support required to support the filled cells. The grout formula will be formulated to meet the project end-state goals. Accumulated amounts of Pu-238, if present in the cells, may be mixed with the grout, microencapsulated, or handled as determined by the safety analysis of the project end-state. The grouted volume can be size reduced and disposed at WIPP during facility demolition.

Grout was selected over the EKOR™ because of the EKOR™ high cost and potential problem with adherence to stainless steel. InstaCote®-ML is best applied as a coating and not as an encapsulate for materials.

References

1. DOE Innovative Technology Report, LAUR 03-4231, Cerium Nitrate Technique for Decontamination of Gloveboxes, June 2003.
2. DOE Innovative Technology Report, LAUR 03-2182, Commercial Three-Step Technology for Decontamination of Gloveboxes, June 2003.