# MODERN STRIPABLE COATING METHODS

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## ABSTRACT

Strippable coatings, loosely adhered paint-like films, have been used for decades in the nuclear industry to decontaminate radioactive equipment, prevent contamination and fix contamination in place. Decontamination of radioactively contaminated surfaces is an ongoing concern in the Department of Energy (DOE) and commercial nuclear industry. Typically, decontamination is employed to reduce worker exposure to radiation and radioactive contamination. Various types of strippable coatings are innovative decontamination methods that are continuing to be developed and used.

Modern strippable coatings show high decontamination efficiencies and have overcome many of the shortcomings of the original coatings. Strippable coatings and self-stripping coatings now rival chemical and mechanical decontamination. Results from radioactive and non-radioactive testing at the Idaho National Engineering and Environmental Laboratory (INEEL) compare the effectiveness of several strippable coatings. Strippable coatings also have the advantages of less waste, non-liquid waste, less expensive, and are relatively simple to apply.

A new strippable coating method, the ADA Technologies ElectroDecon method, is featured in this report. This method utilizes an electric current passed through the coating to draw contaminants from the surface. This method has shown excellent results in the decontamination of stainless steel and should be appropriate for other conductive materials. The ElectroDecon process has been tested with actual radioactive materials as well as simulated contamination.

## INTRODUCTION

Strippable coatings, made from loosely adhered paint-like films, have been in use for five decades. The first commercial strippable coating was the ALARA 1146 product supplied by the Imperial Coatings Company (now the Carboline Company). This coating is used in both the DOE and commercial nuclear sectors in multiple applications to fix contamination in place, provide a barrier against future contamination, and to remove loose contamination like dust.

ALARA 1146 paved the way for other strippable coatings with a wide range of applications. A sample of these coatings is given below:

- TLC Stripcoat, marketed by Bartlett Nuclear, Inc., a similar type of strippable coating to the ALARA 1146.
- PENTEK 604, PENTEK Inc., a "self-stripping" type of coating that peels away from the substrate as it cures
- Sensorcoat, developed by the Los Alamos National Laboratory, a strippable coating that changes color as it comes into contact with plutonium or uranium.
- ElectroDecon, ADA Technologies, Inc., an electrochemical decontamination method using a strippable coating

This list gives but a few of the numerous types of strippable coatings that have been used around the world.

At the INEEL, many different strippable coatings have been used for radioactive decontamination. Tests have been conducted using the ALARA 1146, PENTEK 604, TLC Stripcoat and ElectroDecon method to compare the efficiency and utility of these methods. Several field applications (used on radioactively contaminated equipment) have been performed for the TLC Stripcoat, PENTEK 604 and ElectroDecon products.

## STRIPPABLE COATING APPLICATIONS AT THE INEEL

A series of laboratory tests were conducted in the late 1990s at the INEEL to compare the relative decontamination ability of three different strippable coatings.(1) These coatings were chosen for their prompt availability and compatibility with our site waste disposal systems. The decontamination efficiency of these materials was assessed using simulated contamination (SIMCON) coupon comparisons. The results of those SIMCON tests are shown in Table I.

**Table I. Comparison of Strippable Coatings With SIMCON Coupons.**

| Stripcoat Material | SIMCON I Cs (% Removal) | SIMCON I Zr (% Removal) | SIMCON II Cs (% Removal) | SIMCON II Zr (% Removal) |
|---|---|---|---|---|
| TLC Stripcoat | 87 | 66 | 42 | 73 |
| ALARA 1146 | 83 | 76 | 45 | 76 |
| PENTEK 604 | 96 | 90 | 57 | 75 |

The SIMCON coupons used for these tests are stainless steel disks about ¼" in thickness and 1" in diameter that are doped with non-radioactive salts of cesium and zirconium. SIMCON I coupons simply have the salts dried on the surface, while SIMCON II coupons have the salts dried onto the surface, baked in an oven at 700 deg C for 24 hours, and a water wash used to remove loose materials. SIMCON I is comparable to loose surface contamination and SIMCON II is comparable to fixed contamination. An X-Ray Florescence (XRF) analysis is used to determine the amount of zirconium and cesium on the SIMCON coupons both before and after cleaning. "Percent removal" factors are then determined by comparing the data.(2)

These tests determined that TLC Stripcoat and ALARA 1146 are both relatively easy to use. These two coatings are similar and have roughly the consistency of latex paint. TLC Stripcoat may be brushed, sprayed, or even poured on a surface and peels very easily. ALARA 1146 is difficult to remove if not sprayed onto the surface to achieve a uniform coating thickness of about 1 mil. If applied by brush or other method, it tends to be very difficult to peel. Some operating experience at INEEL using ALARA 1146 has shown that this type of coating is difficult to use in the reprocessing environment, and returned little benefit, removing only loosely held contamination.

The ALARA 1146 strippable coating was also compared to another, non-coating type methods at the DOE Savannah River Site in 2000.(3) In these tests the strippable coating was applied on walls, floors, and equipment at the 321-M Fuel Fabrication Facility. In this comparison, 82% of loose uranium oxide contamination was removed. When compared with the baseline technology of steam-cleaning (where a removal percentage was not determined) the ALARA 1146 was found to have a cost savings for relatively small (<3,408 sq. ft.) applications. In particular, fewer people were required and less waste was produced using the strippable coating, though overall productivity was higher with the steam-cleaning baseline.

PENTEK 604 self-stripping coating is a bit different than the paint like coatings, and its unusual nature prompted further testing by the INEEL engineers. PENTEK 604 is better at decontaminating SIMCON I coupons than the other strippable coatings. This coating has the appearance of honey and is highly viscous. PENTEK 604 was brushed on the surface of SIMCON I coupons and left to dry in a room with a temperature of approximately $60^0$ F. The coupons were checked after 5 hours and 90% of the coating had released from the surface. The coupons were left overnight to finish drying. The coupons were checked the following day and all the coating had released from the coupons.

Several field trials of PENTEK 604 using radioactively contaminated materials were performed to demonstrate removal of actual contamination. The first such trial conducted was to test the effectiveness of PENTEK 604 on lead brick cleaning. The initial contamination on the lead brick was reduced by a factor of ten. These results are shown in Table II. During the decontamination of the lead brick at INEEL, the strippable coating was applied three successive times. Each application of strippable coating was left to dry for one day. All three coats of PENTEK 604 released from the surface of the brick. The strippable coating did stick to areas where there were deep pores or cracks in the brick. In these areas it was easily scraped off the surface with a small hand scraper.

The total amount of waste that was generated from the three coats of strippable coating was approximately 80 ml of solid material (immersion of the brick would likely generate over 1 liter of waste).

**Table II. Results of Contaminated Lead Brick Cleaning**

| **Applications** | **Before Fixed** β/γ, **Bq/m** | **After Fixed** β/γ, **Bq/m** | **Before Smearable** β/γ/α, **Bq /m** | After **Smearable** β/γ/α, **Bq /m** |
|---|---|---|---|---|
| Brick #1 | * | * | β/γ 78.6, α 0.4 | β/γ 6.3, α 0 |
| Brick #2 | * | 2,500 | β/γ 6.3, α 0 | β/γ 2.5**, α 0 |
| Brick #3 | 2,500 | 1,000 | β/γ 2.5, α 0 | ** |

***** = Unknown, ** = Below Free Release Criteria
(<3.3 dpm Beta/Gamma and <0.16 Alpha dpm smearable)

Five "Criticality Barriers" underwent decontamination testing as part of these PENTEK 604 trials. These stainless steel plates were used in the fuel pools to separate stored spent fuel and were contaminated with low levels of cobalt-60 and cesium-137. They didn't have to be cleaned to free release criteria but the contamination level had to be low enough so that they could be removed from the building and transported to another facility for cutting. The coating was applied to both sides of the barrier using a paintbrush and then left to dry overnight. PENTEK 604 was able to remove the smearable contamination from the lids. However, a small amount of fixed contamination remained, preventing free release. The results from this test are shown in Table III.

**Table III. PENTEK 604 Cleaning Results for Criticality Barriers Lids**

| Item | Smearable Before Beta/Gamma (Bq /100cm$^2$) | Smearable Before Alpha (Bq /100cm$^2$) | Smearable After Beta/Gamma (Bq /100cm$^2$) | Smearable After Alpha (Bq /100cm$^2$) |
|---|---|---|---|---|
| Barrier Lid #1 | Front 732.4<br>Back 2211.4 | Front 5.8<br>Back 12.6 | Front < 16.7<br>Back 22.2 | Front < 0.3<br>Back 0.4 |
| Barrier Lid #2 | Front 226.6<br>Back 348.9 | Front 4.0<br>Back 3.3 | Front < 16.7<br>Back < 16.7 | Front < 0.3<br>Back < 0.3 |
| Barrier Lid #3 | Front 864.3<br>Back 206.0 | Front 7.5<br>Back 1.7 | Front < 16.7<br>Back < 16.7 | Front < 0.3<br>Back < 0.3 |
| Barrier Lid #4 | Front 375.2<br>Back 167.2 | Front 3.2<br>Back 1.7 | Front < 16.7<br>Back < 16.7 | Front < 0.3<br>Back < 0.3 |
| Barrier Lid #5 | Front 271.6<br>Back 1117.9 | Front 2.1<br>Back 8.15 | Front < 16.7<br>Back < 16.7 | Front < 0.3<br>Back < 0.3 |

Two other field trials were successfully completed using the PENTEK 604 self-stripping coating. One was to decontaminate a metal plate covered with "ROVER" ash. The ROVER fuel reprocessing process was being decommissioned and a metal artifact was secured for testing. ROVER used large fluidized burners to incinerate graphite fuel for subsequent dissolution and recovery of the uranium. The "greasy", partially burned, graphite is very difficult to remove and often requires very harsh chemicals with lots of scrubbing. A 1' x 1' Hastalloy-X (a high cobalt steel) plate contaminated with ROVER ash was obtained. The plate was coated with one coat of PENTEK 604 using a small paintbrush and left to dry for about 16 hours. The next morning most of the coating had fallen off the surface and only a small portion had to be scraped off. The contamination levels fell from 20,482 dpm beta/gamma to 182 dpm and from 1,768 dpm alpha to 11 dpm with the one application. Though the use of PENTEK 604 was never widespread in the ROVER decommissioning project (nearly all the material was simply removed and disposed of as is), limited use of this product was adopted. The second minor application of the PENTEK 604 material was to clean a cesium capsule in the analytical laboratories. This capsule was made of stainless steel and used for routine sample preparation of cesium-contaminated soils. The contamination was significant and was interfering with the chemical analysis routine. Two applications of PENTEK 604 coating decontaminated the capsule, the threaded lid, and the rubber gasket, thereby saving the $1000 cost of replacing the capsule.

While the paint type coatings were easy to spray using conventional paint sprayers, the PENTEK 604 material was not conducive to spray application. This presents a concern, particularly in the nuclear industry where radiation dose concerns dictate rapid application. A series of tests were conducted at the INEEL to optimize a spray application of the PENTEK 604 coating. A one-quart, automotive type, spray gun was used for applications. It was found that a ratio of 1 part coating to 1 part water worked the best. Spray pressures between 25 and 30 psig produced the best results. Each item was sprayed with the coating so that the entire surface was covered (the coating was not dripping off the surface). After the spray coating application, each item was left to dry for approximately 1 minute before another coat was applied. Three coats with one-minute drying time between each coat were found to achieve 100% release of the coating from the surface. During this test a wrench, a stainless steel block, shoe covers and fiberglass grating were sprayed to see if the coating would release from the surface of these items; the coating released from all these items. Unfortunately, PENTEK 604 is not available at this time, though PENTEK has noted that a higher demand would facilitate a new stock.

A field trial of the TLC Stripcoat material was conducted to determine if this material was a satisfactory barrier and fixative in the INEEL Tank Farm. Old, previously contaminated concrete prevented the routine use of a concrete tank penetration riser in the Tank Farm and decontamination was needed. However, placing and removing a robotic arm from the riser would spread contamination in the area and result in repeated decontamination cycles. A "garden sprayer" type apparatus was used to apply a thick coating of TLC, which (when dry) was surveyed by the radiation/contamination technicians (RCT) and found to have a low contamination surface. After insertion of the robotic arm, another layer of the coating was applied over the original coating effectively creating a contamination "sandwich" which can be removed and disposed of as solid, low-level waste. This was particularly important, because no liquid waste could be spilled into these tank risers and a non-chemical decontamination means was necessary.

**ELECTROCHEMICAL STRIPPABLE COATING DEVELOPMENT**

The ADA Technologies Inc., (ADA) ElectroDecon (ED) system, originally designed to decontaminate contact handled metal objects, such as glove boxes, is being developed as a non-liquid, waste minimization tool for cleaning a highly radioactively contaminated metal. This system was proven effective for removing simulated contamination at the Idaho INEEL in 2001(4) and in early 2002 was used to clean radioactively contaminated materials.(5) This work lead to a project supported by the West Valley Demonstration Project (WVDP, a Department of Energy facility in West Valley, New York) to develop the ED technique into a tool designed for use in a hot cell environment.(6) The ED System remains as a prototype undergoing final development and commercialization at this time.

The ED system operates on the principle that positively charged, radioactive cations will be drawn to a negatively charged anode and captured in the ED gel. The ED system uses a gel as the electrolyte. The gel dries after a few hours and forms a loosely adhered coating (a strippable coating) that contains the removed radioactive cations. The coating is removed and disposed of as a solid waste. The system shown in Figure 1 is the original scrubbing shoe designed to apply the ADA's proprietary electrolyte gel to a contaminated surface. The other components are: power supply, an electrolyte pump module, electrolyte and current supply tether, anode terminal, abrasive scrub pads, and electrolyte gel pack.

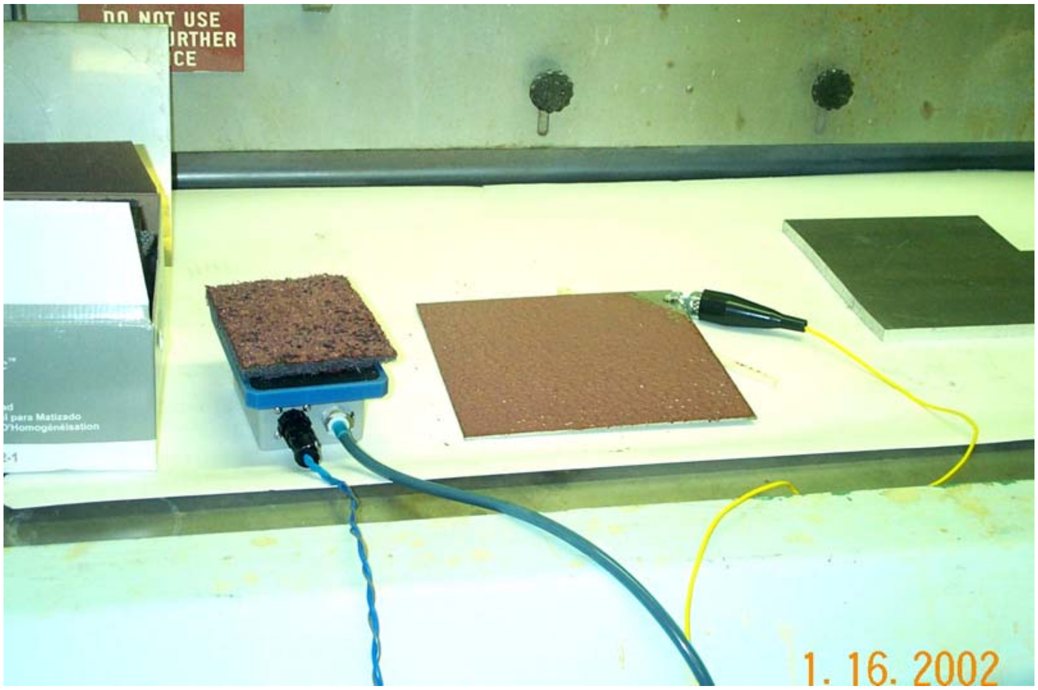


**Fig. 1. Scrubbing shoe and electrode setup.**

During operation, the average current measurement was approximately 2 amps. Gentle scrubbing action of the pad on the surface stirs the electrolyte and brings fresh gel into the interface, increasing the rate of contamination removal. Following passage of the electrical current, additional electrolyte gel is applied through the scrub pad and, using the scraper edge on the sole plate, spread into a relatively smooth layer of sufficient thickness to permit post-cure removal. After a period of time to permit curing (approximately 2 hours for 15-25 mil thick layer), the coating may be stripped away from the surface.

The INEEL has performed four tests of the ED method over the past five years. The first test of the method used SIMCON II coupons only. The ED method performed very well for these coupons, though it was not particularly well suited for use in a test of a small one-inch coupon. The results from these 1999 tests are shown in Table IV. Based on these successful results a radioactive test of the method was scheduled. Two criticality barriers were used for this study.

**Table IV. ADA Technologies ED Testing**

| Testing Parameter | Cs, SIMCON II Percent Removed | Zr, SIMCON II Percent Removed |
|---|---|---|
| Standard conditions | 92 | 89 |
| Extra time treatment | 98 | 95 |

Criticality Barriers (as described in the PENTEK 604 field trials) have one side of the plate that has consistently higher initial radiation readings (Side 1) than the other side (Side 2). Without removing any contaminant from the test articles, the sides with high initial contamination were placed face up and decontaminated by the ADA' ElectroDecon method. A total of approximately 10 minutes was used to apply the electrolyte gel, moderately scrub the surface, and pass current through the interface. Table V lists the results of a radioactivity survey on the sample surface of both criticality barriers before and after decontamination. It shows that more than 80% of the initial gross radioactive contaminant was removed in the first application. The swipe samples collected from the sample surface fell below the detectable limit after the initial application. The test was repeated on the previously decontaminated surface of the first test article, further reducing the surface radioactivity from approximately 8000 dpm/100 $cm^2$ to approximately 4000 dpm/100 $cm^2$. The major, loose contaminants were determined to be $^{60}Co$ and $^{152}Eu$, based on analysis of the swipe sample analyses.

**Table V. Decontamination on Criticality Barrier Surface (Side 1) from ED Method**

| Radioactivity Measurements | | Test Article 1 | Test Article 2 |
|---|---|---|---|
| Pretest | | | |
| Direct Scan | Geiger Counter (βγ, Bq/100 cm$^2$)* | 833.3 | 750.0 |
| | Surface Dose (μSv/hr) | 15 | 10 |
| Swipe Sample (dpm/100 cm$^2$) | βγ** | 231.7, 185 | 303.3, 191.7 |
| | α** | 3.8, 2.6 | 5.2, 3.3 |
| After 1st Decontamination | | | |
| Direct Scan | Geiger Counter (βγ, Bq/100 cm$^2$)* | 133.3 | 100 |
| | Surface Dose (μSv/hr) | <1 | <1 |
| Swipe Sample (dpm/100 cm$^2$) | βγ | <16.7 | <16.7 |
| | α | <0.3 | <0.3 |
| % Removal | βγ (Bq/100 cm$^2$, direct scan) | 84 | 87 |
| After 2nd Decontamination | | | |
| Direct Scan | Geiger Counter (βγ,Bq/100 cm$^2$)* | 66.67 | NA |
| | Surface Dosage (μSv/hr) | <1 | NA |
| Total % Removal | βγ (Bq/100 cm$^2$, direct scan) | 92 | NA |

* Peak reading of the test article surface, fume hood floor has background of 50 Bq/100 cm$^2$.
** Samples from different locations of test article.

The third set of INEEL tests focused on the modification of the ED system for use as a remotely operated decontamination tool. Significant modification of the ED applicator pad was required to adapt the ED system for use remotely in the hot cell environment. The original ED system required that use and maintenance be performed “hands on”. It was not designed for use with a master slave (or PaR electromechanical manipulator), which has limited dexterity and freedom of movement. The changes required, and approaches taken are listed in Table VI and shown in Figures 2 and 3.

**Table VI. Problems and Modifications Made to the ED Equipment.**

| Issue | Modification needed | Design approach |
|---|---|---|
| Create manipulator compatible handle. | Standard tool would not conform to being gripped with a manipulator. | New design was developed to aid gripping scrub shoe. |
| Tube and scrub shoe tended to plug with unused gel after use. | A mechanism was needed to clean out the shoe and tubing when finished. | An air manifold was installed to clear out the shoe and tubing. |
| The switch was located on the scrub shoe where it could not easily be operated. | Move the switch to an area convenient to the operator and away from the shoe. | A foot switch was added to the unit to allow the operator to use his hands for manipulating the scrub shoe. |
| The Scotch-Brite® pad on the bottom of the scrub shoe was not change to remove remotely. | Modify the attachment mechanism and make it suitable for remote application. | A new type of attachment was designed and a work area plate was built to facilitate attaching and removing the Scotch-Brite® pad. |
| Some areas might require additional length to reach beyond the manipulator limit (like ceilings or floors). | Add a reach rod accessory to allow additional length. | A reach rod was made that can be added to the scrubbing shoe. |
| The coating may not be easily removed (stripped) from the wall surfaces. | Fabricate tools to aid in removing the dried coating. | Several tools were built/modified and tested to remove leftover coating. |
| The cathode clamp was not compatible with in cell work. | Fabricate a cathode that would not have to be "clamped" to the large, flat areas. | A suction cup device was prepared that used a spring cathode connection. |

The remote ED project demonstrated that this technology could be useful in decontaminating a highly radioactive stainless steel lined hot cell. The system was tested in the Remote Test Mockup Facility at the INEEL using two different kinds of manipulators. The primary objectives of the test were reached; deploying the system on a vertical surface using a PaR electromechanical and master slave manipulators and demonstrating the removal of contamination. The system failed to fully perform in the areas of usability on ceilings and in coating removal. These are areas that improved performance should easily be obtained with more equipment development.

**Fig. 2. Modified ED Applicator Pad and Maintenance Fixture.**

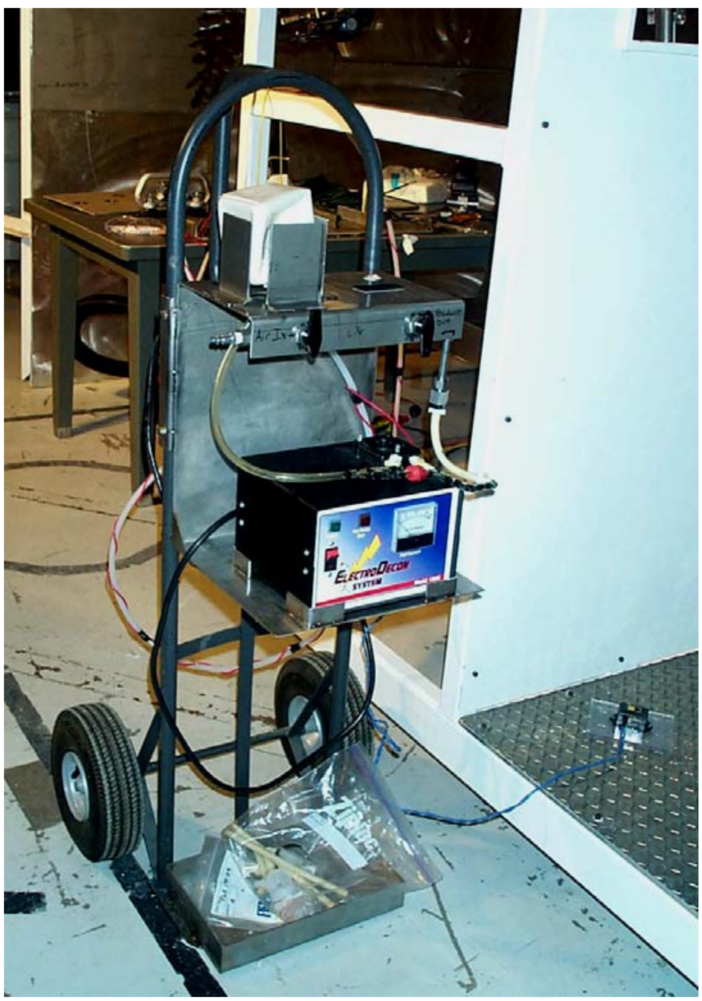


**Fig. 3. ED Control Unit Modified for Remote Use.**

The efficiency of removal was simulated using a “Sharpie” permanent marker ink test. Several, approximately 0.25 “ wide, lines of marker ink were placed on the stainless steel plate and left to dry (for a period of about 1 hour). Sharpie Marker is a fairly rigorous test in that water and most solutions will not remove it from a surface. A typical application of the electrochemical gel was made to this area. After 24 hours the dry coating was stripped from the wall. A slight amount of ink was visible, but more than 80% of the mark was removed. This was repeated with several other ink markings that came on the stainless steel. These were removed and transferred to the transparent strippable coating.

For the fourth laboratory test of the ED system, five more critically barriers were used. Between 5 and 10 minute cleaning applications were used to apply the electrolyte gel, moderately scrub the surface, and pass current through the interface. A minimum of 2 hours of cure time was adopted prior to stripping the coating away from the surface. One plate, 3A (shown in Figure 4), was tested in a vertical application. Table VII lists the test conditions, and the results of radioactivity survey on the surface of all five critically barriers before and after decontamination. Based on swipe sample analyses, the major contaminants were $^{60}$Co, $^{137}$Cs and $^{152}$Eu. However, the contaminants shown in the coating samples after drying were $^{60}$Co, $^{95}$Zr, $^{137}$Cs, $^{152}$Eu, $^{154}$Eu and $^{155}$Eu. This difference is noteworthy in that different radioisotopes were obtained in these two analyses; the fixed contaminant distribution not being entirely representative of the loose contamination.


**Fig. 4. ADA Technologies ElectroDecon System Being Used to Clean Criticality Barrier.**

**Table VII. ADA ElectroDecon Evaluation Summary**

| Radioactivity Measurements (1) | | Test Articles and Applied Current Parameters | | | | |
|---|---|---|---|---|---|---|
| | | 2A | 3A | 4A | 5A | 6B |
| | | 10 minutes, normal | 5 minutes, normal (3) | 5 minutes, reverse | 5 minutes, normal | 7 minutes, reverse |
| Pretest | | | | | | |
| Direct Scan | Geiger Counter (βγ, Bq/100 $cm^2$) | 2,333.3 | 250 | 416.7 | 500 | 2,000 |
| Swipe Sample (Bq/100 $cm^2$) (2) | βγ | 224.4 | 26.6 | 9.7 | 8.1 | 104.8 |
| | | | | | | |
| After Decontamination | | | | | | |
| Direct Scan | Geiger Counter (βγ, Bq/100 $cm^2$) | 83.3 | 83.3 | 83.3 | 50 | 166.7 |
| Swipe Sample (Bq/100 $cm^2$)(2) | βγ | 0.6 | 0.4 | 0.1 | 0.5 | 0.1 |
| Total % Removal | βγ (direct scan) | 96 | 67 | 80 | 90 | 92 |
| | βγ (swipe sample) | 99 | 99 | 99 | 94 | 99 |

Note: (1) Background in hood: 0.5 μSv/hr, 33.3 Bq/100 $cm^2$ βγ
(2) α analyses of all swipe samples: <0.3 Bq/100 $cm^2$
(3) Test article position at 60° angles from the horizontal surface

Development of the ED system continues with the current emphasis on examining the impact of applied voltage, tensile strength of the coating and user interface on decontamination effectiveness. Improvements in these areas are viewed as the final steps to commercializing this system. The INEEL is collaborating with ADA Technologies in this final push to make the ED system available to the public. A contract is in place for field trials of the latest prototype developed in the Fall of 2004. This system will likely be placed into service in a decommissioning project at the INEEL.

## RESULTS AND CONCLUSIONS

The tests conducted by the INEEL and other facilities, along with the historical application of many strippable coatings, demonstrate that strippable coatings are significant, innovative tools for decontamination. The results of tests with SIMCON coupons place the coatings well within the decontamination efficiency range of routine mechanical and chemical decontamination technologies. With use, the familiarity of these coatings has prompted increased acceptance and use at the INEEL. But the real significance of using strippable coatings is found in their ease of application and minimal waste volume produced.

A truly novel technique, the ElectroDecon system, developed by ADA Technologies, Inc., offers superior decontamination efficiency. Tests by the INEEL have proven this technique's effectiveness and versatility. Further development has shown that a remote application of the gel system is possible. This system is in the final stages of development and should be commercially available soon.

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