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REDUCTION IN SOLVENT-BASED COATINGS AT THE SAVANNAH RIVER SITE

Eric Skidmore, Shyam Thakur, Rick Hiller*
Westinghouse Savannah River Company, Aiken, SC
*Sherwin-Williams Company

Abstract

The Savannah River Site (SRS) is one of the U.S. Department of Energy (DOE) nuclear materials production sites, covering approximately 300 square miles near Aiken, SC. The SRS has operated since 1954, producing plutonium, tritium, and other nuclear materials critical for national defense. The SRS is a large complex that includes nuclear reactors, fuel/target fabrication, chemical separation facilities, radioactive waste storage and processing facilities, research laboratories and a supporting infrastructure for water treatment and steam generation. Protective coatings have been used at the SRS for more than 50 years to provide corrosion protection and to facilitate radiological decontamination. Most of the protective coating systems used have been solvent-based. The site has developed a new coatings program encouraging the use of waterborne and lower VOC coatings where feasible, reducing personnel hazards as well as application and disposal costs.

Background

The Savannah River Plant (SRP), which covers approximately 300 square miles near Aiken, SC was constructed and operated by the E.I. DuPont Company starting in the early 1950s. The purpose of the SRP was to produce plutonium, tritium and other nuclear materials critical for national defense. Independent facilities for fuel fabrication, heavy water manufacture, nuclear reactors, chemical separations, radioactive waste storage/processing, and laboratory support and development were all constructed to meet these needs. In 1989, the Westinghouse Savannah River Company took over operation of the plant, renamed the Savannah River Site (SRS).

In recent years, the missions of the SRS have changed primarily as a result of the Cold War ending and nonproliferation policy. The nuclear reactors are no longer operational, and some facilities have been converted to new missions. Currently, the main missions of the SRS are to process and stabilize legacy radioactive waste material, receive and store consumed non-commercial nuclear fuels, and to safely store plutonium-bearing materials until final disposition. New missions in progress include the Mixed Oxide (MOX) Fuel Fabrication Facility for the conversion of weapons-grade plutonium into mixed oxide fuel for use in commercial power reactors.

Protective Coatings at SRS

Most major SRS facilities were built in the 1950s and 1960s. These included facilities for nuclear fuel/target fabrication, heavy water manufacture, nuclear reactors, chemical separations, solid and liquid radioactive waste storage, and the supporting infrastructure. The major SRS facilities and the coating systems used therein are discussed.

Reactors

In SRS reactors, target assemblies and aluminum-clad uranium fuels were irradiated to produce the desired isotopes. The floors and walls of the primary containment structure were coated with either vinyl chloride-acetate copolymers (solution vinyls) or nuclear-tested epoxy coatings for radiation resistance and decontaminability (Figure 1). Early alkyd enamels were used in some areas but were later replaced with more robust epoxy coatings to better survive radiation and decontamination exposures.

The main structural building of the SRS K-Reactor was recently converted into the K-Area Materials Storage (KAMS) facility for the storage of plutonium-bearing materials (Figures 2-3). As part of the upgrade, nuclear-tested epoxy coatings were used on the KAMS facility floors and walls for radiation resistance, decontaminability, and compliance with fire protection standard NFPA 801, a recent requirement for DOE nuclear facilities. NFPA 801 requires that interior finishes of non-commercial nuclear facilities meet certain flame spread, smoke development and heat flux (floors only) requirements.

In the reactor areas, concrete basins were built to store aluminum-clad uranium fuels. The oldest reactor basins were lined with vinyl copolymers, while later storage basins such as the RBOF Receiving Basin for Off-Site Fuels (RBOF) Facility were lined with early epoxy-phenolic coatings in the 1960s (Figure 4). The RBOF facility was recently closed, and only the newer L-Basin remains operational.

Separations Areas

Special facilities historically known as the “canyons” were constructed for the reprocessing of nuclear fuels and targets in the chemical separations areas (F &H). The buildings were so named because of their long narrow shape and deep open (Figures 5-6). They are about 835 feet long, 122 feet wide and 66 feet high. The canyons are comprised of multiple cell sections, each approximately 43 feet long. A center section is divided into four floors or levels, separating the warm and hot side of each canyon facility. The center section contains office space, the facility control room, and various support equipment. The canyon walls are made of 4-foot thick reinforced concrete for radiation shielding and structural integrity.

In the canyons, aluminum-clad uranium fuels were historically dissolved in boiling concentrated nitric/hydrofluoric acid solutions, followed by complexing, precipitation and purification steps to obtain the desired products. These aggressive solutions are handled in equipment made of 304L stainless steel or higher alloys for corrosion resistance. These processes are operated remotely due to extremely high radiation levels (Figure 6).

In addition to uranium and Pu recovery, the canyons were equipped with special capabilities to recover special isotopes such as neptunium-237 (Np-237) and plutonium-238 (Pu-238) from the reactor fuel and special irradiated targets. Pu-238 oxide heat sources for the NASA Galileo and Cassini deep space mission were produced at the SRS HB-Line facility (Figure 7).

To protect against chemical attack, the canyon walls and floors and were originally coated with a highly catalyzed, heat-cured (140-160°F) monolithic system. Most of the other facility surfaces and equipment such as crane maintenance areas, shielding doors, and cold feed preparation rooms were coated with solution vinyls for radiation/acid resistance. Over the years, maintenance and removal or disposal of these coatings has become more problematic due to environmental regulations and radioactive contamination.

Early canyon cranes were coated with either solution vinyls or nuclear-tested epoxy/polyurethane coatings (Figure 8). In the late 1980s, replacement canyon cranes were made almost entirely from stainless steel in order to reduce personnel exposure associated with decon and coating maintenance activities. In cold feed preparation areas, specialized coatings such as graphite flake-filled vinylesters are used for secondary containment of strong nitric acid solutions. The graphite additive provides for low surface energy for ease of cleaning and decontamination.

High-Level Waste (HLW) Facilities

Highly radioactive liquid waste from the canyons is pH-adjusted (12-14+), concentrated through evaporation and transferred to special underground carbon steel waste tanks in the F and H-Area tank farms (Figure 9). Approximately 35 million gallons of high-level radioactive waste is currently stored in 49 tanks until it can be converted through the Defense Waste Processing Facility into a solid form. The HLW tanks are enclosed in concrete for structural stability and radiation shielding. The concrete tank tops are coated with nuclear-grade epoxy/polyurethane systems for chemical resistance, decontaminability, and good weatherability. In the early days, vinyl copolymers were used in below-grade diversion boxes and pump/valve pits. More recently, plural-component, fast-cure polyurea coatings have been used on the tank tops for radiological contamination control (Figure 10).

The waste is transferred via underground stainless steel piping jacketed within carbon steel pipe for secondary containment and leak detection. Several methods are used to protect the steel jacket lines from corrosion, including protective tape wraps, extruded polyethylene, fusion-bonded epoxy, inorganic zinc coatings embedded in hydrophobic powder, and coal tar epoxy coatings. Coal tar epoxies have been recently replaced with micaceous iron oxide-filled epoxy phenolic coatings to reduce application hazards.

The SRS also has one of the largest aboveground steam line systems in the world, connecting areas separated by several miles for security purposes. As typical in other industries, many of these lines are coated with immersion-grade epoxy, epoxy-phenolic or fusion bonded epoxy coatings suitable for use under thermal insulation, with inorganic zinc and high-heat silicone coatings used for higher temperatures. Galvanized steel and zinc-rich coatings are not used on lines subject to temperatures less than 250°F where hot/wet conditions and galvanic reversal could occur. Non-absorbent insulations such as cellular glass are used where possible.

Defense Waste Processing Facility (DWPF)

The DWPF, the largest radioactive waste vitrification facility in the world, began radioactive operations in 1996 (Figure 11). Waste from the H-Area tank farm is mixed with formic and nitric acids and borosilicate glass frit in the receiving area. The slurry is melted at 1100-1150°C in a large glass melter and poured into 10' tall, 2' diameter stainless steel canisters (Figure 12). The canisters are cooled and sealed, then transferred to a storage building and stored in underground cells until final disposition. To date, approximately 2000 canisters have been poured. The DWPF is expected to process high-level waste until the year 2020.

Robust vinyl ester coating systems were specified for the DWPF canyon floors for chemical resistance, radiation resistance and decontaminability. The floor, walls and ceilings in analytical cells and some non-rad areas are also coated with nuclear-grade epoxy systems for decontaminability. The floor slab and cell plugs in the canister storage building are topped with a 1" thick, silica fume-enhanced cement-based metallic aggregate system to withstand the heavy loads imposed by the canister transport vehicle (Fig. 13).

SRNL Waste Collection System

The Savannah River National Laboratory provides technical and R&D support for SRS facilities, often involving laboratory scale experiments to develop new processes or to solve operating issues. The SRNL waste collection system consists of underground transfer lines that carry high and low-level radioactive waste solutions to stainless steel collection tanks located in underground concrete cells. The cells and pipe galleries are still lined with the original vinyl copolymer coatings that were applied in the 1950s. These coatings have remained in excellent shape after many years of service (Figure 14).

SRS Coatings Program

During DuPont's early years as the site prime contractor, many of the coating products used were manufactured by DuPont. In later years, plant coating specifications became more generic, with multiple products approved. Over time, the number of coating systems increased to well over 60, making coating projects and maintenance more difficult to manage.

For the last few years, the SRS has had a strategic sourcing contract with a major coatings manufacturer to provide architectural and protective coatings, technical support and inspection services. This approach has provided many benefits such as unified product selection, lower product costs, extensive technical support and on-site inspection services. Alternative products can be used upon review.

As in other industries, the need to reduce costs associated with coatings work while still ensuring worker safety and project quality has led to changes in SRS coating specifications. The SRS Construction Department (Bechtel Savannah River Inc.) recently employed the Six Sigma approach to evaluate site coatings work practices to achieve cost reduction.

The SRS Construction Department spent \$12.6M (including labor, materials, and subcontracts) executing its coatings scope in FY04. For similar scope in FY05, construction management set a goal of \$12.0M, leaving a \$600K gap. These figures are for site construction projects and do not include the coating usage by site maintenance groups. After reviewing project and procurement documents, it was found that for one 20 month period (January 2002 through September 2004), the percentage of solvent-based coatings utilized at SRS was 78% of the total. The Construction department then set a solvent-based coating usage target of 35%.

A cost analysis was then performed based on average costs for life-cycle application of water-based vs. solvent-based coating materials. The primary factors considered included evaluation of coating application methods and efficiency rates, labor rates, variation in cure times/recoat windows, costs associated with industrial hygiene review and monitoring, protective equipment requirements, and waste disposal costs.

For analysis purposes, all non-architectural coatings were considered solvent-based, even though VOC levels are already quite low for some products. All coatings used at the SRS are already restricted to a VOC level of ≤ 3.5 lbs/gal unless dictated by unusual conditions. Reasons to use lower VOC and waterborne products where possible include: improved worker safety, reduced impact on the environment, reduced costs for environmental or industrial hygiene monitoring, and reduced costs for protective equipment and disposal.

In particular, solvent-based coatings waste used or generated in radiologically contaminated areas must be treated as mixed hazardous waste. If classified as both RCRA hazardous and radiologically contaminated waste, the cost of pretreatment (macroencapsulation) and disposal is approximately \$70/gallon, compared to only \$3.18/gal if not contaminated. The mixed waste cost for stabilization of water-based paint is approximately \$20/gallon. Though the amount of waste classified as mixed hazardous waste from coatings work is not generally high, the need to reduce this type of waste is obvious. Typically, the coatings or associated items that require treatment are those that contain RCRA levels of hazardous organics, such as methyl ethyl ketone, xylenes, methylene chloride, etc, or contain heavy metals in the pigment, or have a flash point less than 140°F.

Based on review of SRS applications and service environments by both the strategic supplier and site experts, waterborne coatings were deemed suitable for the majority of indoor/outdoor industrial atmosphere exposures where solvent-based coatings were still being used. However, waterborne coatings were not considered suitable for the certain environments without testing. Specifically, waterborne coatings are restricted in areas subject to high radiation, harsh decontamination under thermal insulation, or severe corrosive service.

Working with the strategic supplier, the older coating specification system for aboveground steel was revised to consolidate the number of coating systems needed for most site applications. This reduced the number of coating systems from the previous 60+ down to around 15, greatly simplifying the selection and maintenance process. Approximately 40% of these systems are now water-based.

Waterborne alkyds or high performance acrylics were substituted for solvent-based and higher VOC alkyds in general outdoor/indoor applications, with water-based epoxies and polyurethanes substituted for outdoor applications and non-nuclear/corrosive applications where possible. Solvent-based coatings are now primarily restricted for high radiation areas, areas subject to harsh decontamination, under thermal insulation applications, and secondary containment areas requiring specific chemical resistance.

Cost Analysis Results/Limitations

Based on assumed coating usage, cost savings associated with the identified primary factors, and target reduction in solvent-based coatings, an annual cost savings of \$186K and a savings of \$246K through the end of FY06 was estimated.

Since the actual performance of the newer coatings in SRS applications is unknown, the long-term cost savings may differ from estimated values. In some cases, the cost savings may be negligible depending on location. Protective equipment and monitoring requirements may not change in radiologically contaminated areas due to poor ventilation and restrictions regardless of coating material.

Summary

Protective coatings have been successfully used at the U.S. DOE Savannah River Site for over 50 years for corrosion protection, radiological decontamination, radiation resistance and secondary containment. The latest trends in the protective coatings industry are being followed in the areas of coating selection, specification and performance. A strategic agreement with a major coatings manufacturer has resulted in simplified product selection, material cost reduction, improved technical support and reduced cross-product incompatibility. Recent efforts have resulted in a 40% reduction in use of solvent-based coatings, with an expected cost savings of approximately \$250K through FY06 based on currently planned work scope.

Acknowledgements

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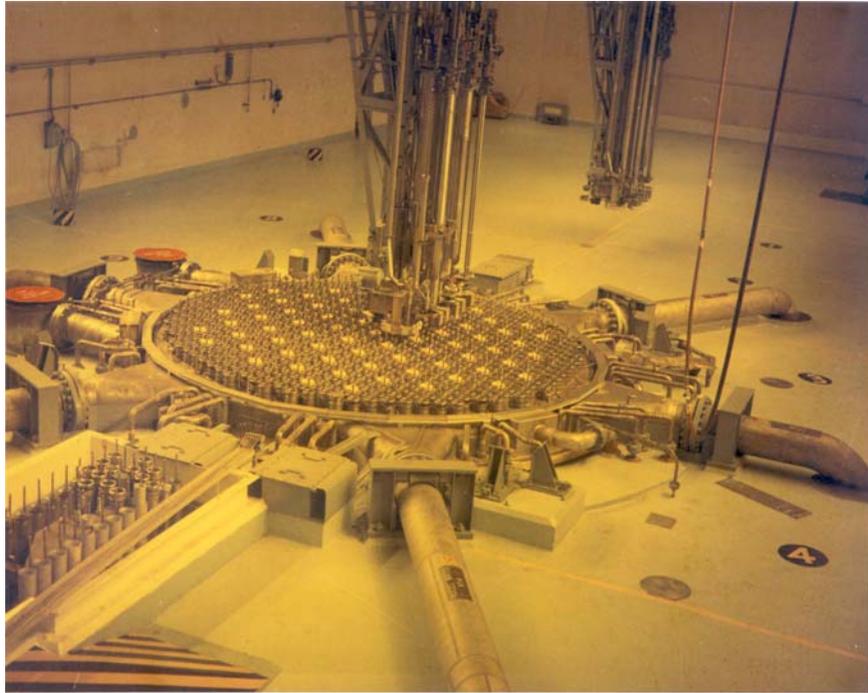


Figure 1. SRS reactor room floor, coated with nuclear-tested epoxy
(Courtesy of SRS Archives, negative DPSPF-11395-9)



Figure 2. K-Area Material Storage (KAMS) Facility



Figure 3. KAMS Interior (floors/walls coated with nuclear-grade/NFPA 801-compliant epoxy)

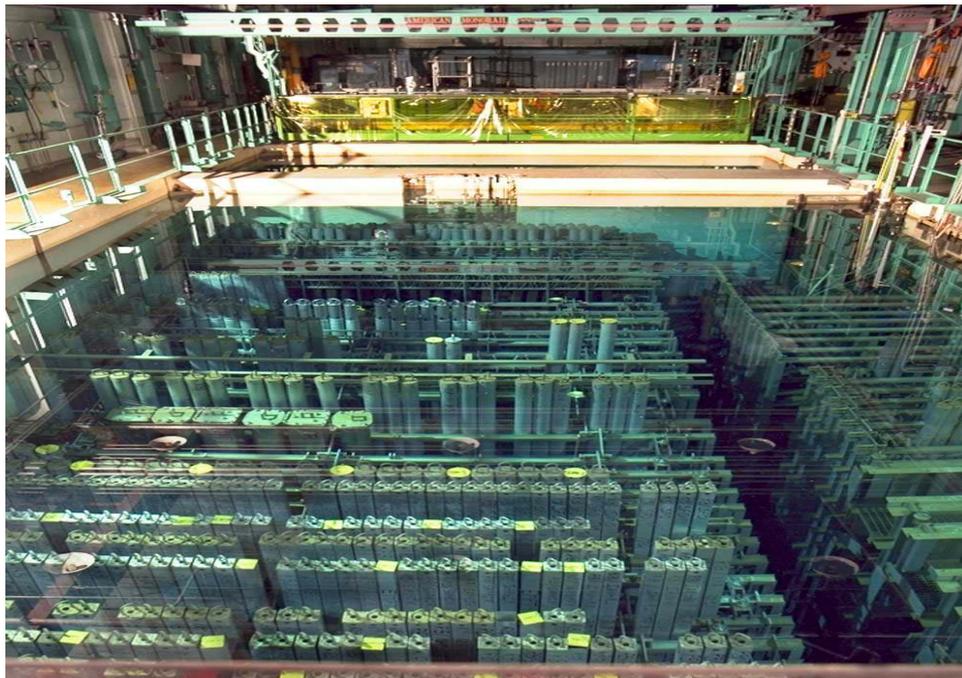


Figure 4. Receiving Basin for Off-Site Fuels (RBOF)
(concrete basin lined with early epoxy-phenolic, 1960s)



Figure 5. Exterior View of H-Canyon Facility.

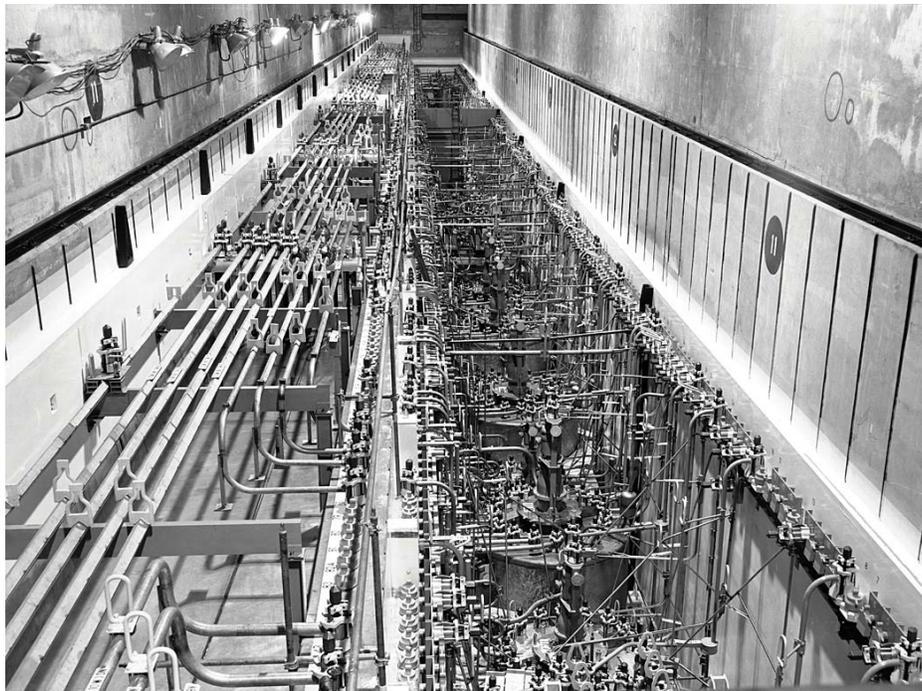


Figure 6. Canyon floors and walls coated with vinyl copolymer coatings, early 1950s
(Courtesy of SRS Archives, negative DPSPF 11568)



Figure 7. Plutonium-238 oxide power source produced at SRS for deep space exploration (SRS Archives, negative DPSPF-35055-1)



Figure 8. Overhead Canyon Crane (coated with nuclear-grade epoxy/polyurethane)



Figure 9. Tops of High-Level Waste Tanks
(coated with nuclear-tested epoxy/polyurethane)
H Area Tank Farm, 1980. Courtesy of SRS Archives, negative DPSPF 30174



Figure 10. Polyurea applied over epoxy primer for contamination control on top of a HLW tank.



Figure 11. Defense Waste Processing Facility (DWPF)

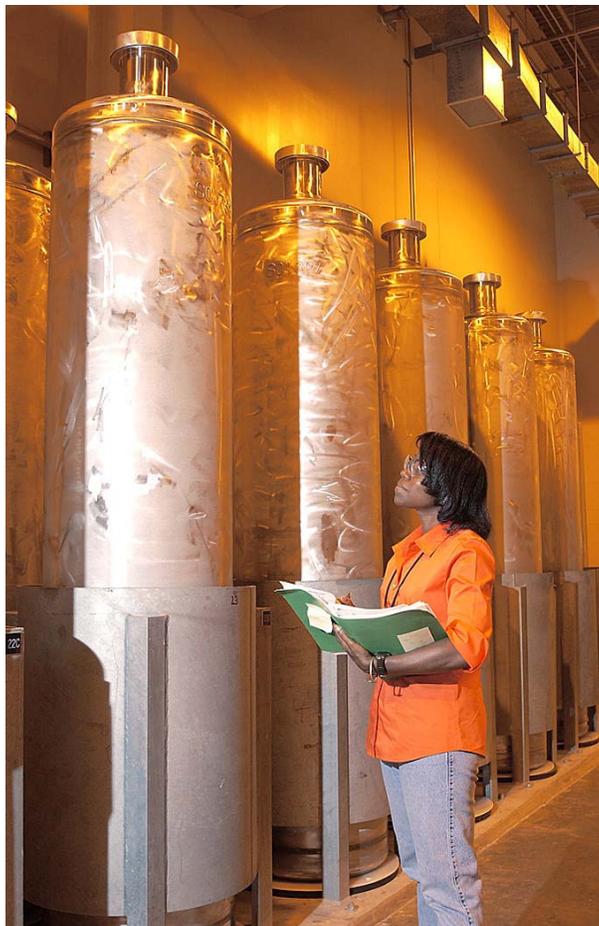


Figure 12. Stainless Steel HLW Canisters



Figure 13. Canister Transport Vehicle in Glass Waste Storage Building
The floor/cell covers are topped with a 1" thick cement-based metallic-aggregate system.

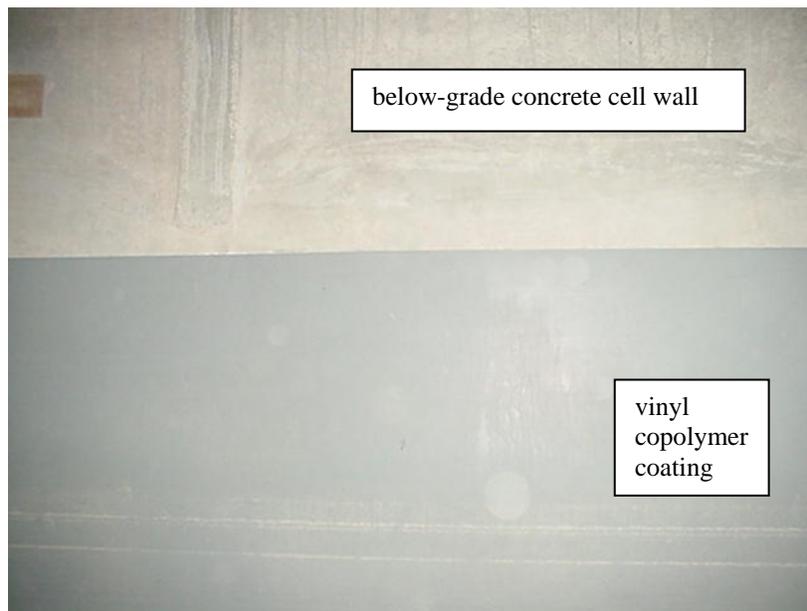


Figure 14. Secondary containment lining in SRNL waste collection cells