# Decommissioning the Dresden Unit 1 Spent Fuel Pool

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## ABSTRACT

The Dresden Nuclear Power Station, Unit 1 Spent Fuel Pool (SFP) (Exelon Generation Co.) was decommissioned using a new underwater coating strategy developed in cooperation with the Idaho National Laboratory (INL). This was the first time that a commercial nuclear power plant (NPP) SFP was decommissioned using this underwater coating approach. This approach has advantages in many aspects, particularly in reducing airborne contamination and in safer, more cost effective deactivation. The process was pioneered at the INL and used to decommission three SFPs with a total combined pool volume of over 900,000 gallons. The INL provided engineering support and shared project plans to successfully initiate the Dresden project.

This report outlines the steps taken by the INL and Exelon on the pathway for this activity. The rationale used to select the underwater coating option and the advantages and disadvantages are shown. Special circumstances, such as the use of a remotely operated underwater vehicle to map (visually and radiologically) the pool areas that were not readily accessible, are discussed. Several specific areas where special equipment was employed are given and a lessons learned evaluation is included.

## INTRODUCTION

A new strategy in decommissioning a commercial nuclear power plant SFP was implemented with the decommissioning project at the Dresden Nuclear Power Station Unit 1. This project was a cooperative effort between Exelon and the INL, sharing project planning, equipment and documentation. The approach was to apply an underwater cleaning and coating process pioneered at the INL. It was successfully modified and deployed by the Dresden Unit 1 SFP team.

The Dresden Station Unit 1 is one of the first commercial nuclear reactors commissioned in the United States. Unit 1 was placed into commercial operation on August 1, 1960 and became the first commercial nuclear power plant built by private industry. It is situated approximately 50 miles southwest of Chicago near the confluence of the Des Plaines and Kankakee Rivers. It shares this site with two other NPPs, Dresden Units 2 & 3.

Unit 1 is a General Electric designed, Boiling Water Reactor. It was designed at a power output of 630 MW thermal (later increased to 700 MWt), generating 210 MW of electricity. It had a history of minor steam leaks and erosion in steam piping. Unit 1 operated until 1978, when it was shut down for retrofitting. In 1979 (after the Three Mile Island incident) additional regulations were issued, and a decision was made not to restart Unit 1. The plant was then licensed to possess radioactive material but not to operate and to move into a SAFSTOR (a Nuclear Regulatory Commission (NRC) interim decommissioning designation) configuration. Chemical decontamination of the primary system was completed in 1984. The remainder of the decommissioning work has been delayed until the other operating units reach the end of their lifetime.[1]

In 2004, a decision was made by Exelon management to reduce the risk of fuel pool leakage by cleaning, draining and coating the spent fuel pool. The Unit 1 tritium groundwater-monitoring program indicated that there was leakage from the Unit 1 pools. There has been no indication of any significant leakage and the tritium monitoring will continue to be used to provide indication of any possible leakage until all the water is drained from the pools. Recent incidents of SFP leakage, particularly at the Indian Point and Connecticut Yankee NPPs, underscore the wisdom of this concern. A conceptual plan was developed in the spring of 2004 to remove the water, process it in the Units 2 & 3 water treatment systems, seal the basin and thus reduce the risk and maintenance requirements for the SFP.

Exelon contacted the INL because word was beginning to spread that a novel method of successful spent fuel pool decommissioning had been developed. The INL is a Department of Energy (DOE) owned, contractor operated nuclear energy development laboratory located 45 miles west of Idaho Falls, Idaho. During 50 years of nuclear research the INL had built several SFPs, four of which were scheduled for decommissioning by 2004. These included the Test Area North (TAN) 607 Pool, the Materials Test Reactor (MTR) 603 Canal, the Power Burst Facility (PBF) 620 Canal and the Idaho Nuclear Technology Engineering Center (INTEC, the former Chemical Processing Plant) 603 Overflow Pit. The large TAN-607 SFP was completed ahead of schedule and for less cost than using traditional practices. The size and condition of the INL pools are shown in Table I.[2]

Table I. INL Spent Fuel Pools Undergoing Decommissioning

| **Pool Designation** | **Volume** | **Dimensions** | **Wall Coating** | **Average Water Contamination** |
|---|---|---|---|---|
| TAN 607 | 780,000 gal. | 48'x70'x24'deep | Painted concrete | 1E-3 uCi/L |
| MTR 603 | 118,000 gal. | 110'x8'x18'deep | Stainless steel | 4E-2 uCi/L |
| PBF 620 | 25,000 gal. | 8'x16'x20'deep | Painted steel | 1E-3 uCi/L |
| INTEC 603 | 11,500 gal. | 6'x8'x17' deep | Bare concrete | 4E-2 uCi/L |

## THE INL APPROACH

Cleaning and coating an SFP using the underwater process requires extensive environmental, safety and health (ES&H) documentation and engineering efforts. The set of procedures, permits and safety analyses for the TAN-607 SFP fill four large binders. Members of management reviewed these preparations and procedures during an assessment prior to commencing the fieldwork. An underwater team with nuclear reactor experience, Underwater Engineering Services (UES) was contracted to perform the cleaning and coating work. Emergency procedures were well documented, reviewed in a pre-job briefing each workday and work was coordinated through the facility management. During each shift of underwater diving, a senior management representative from the INL supervised the contractor's conformance with the safety procedures.

One major part of the INL preparation was developing an "As-Low-As-Reasonably-Achievable" (ALARA) package. Due to the radioactive nature of this work, (portions of the TAN-607 pool had highly radioactive material and the water was moderately contaminated), the work processes and procedures were scrutinized to meet the tightest level of radiological control. Essentially no portion of the work was left to chance in terms of potential skin contamination or overt radiation exposure. This integrated with the training and experience of the underwater diver's program.

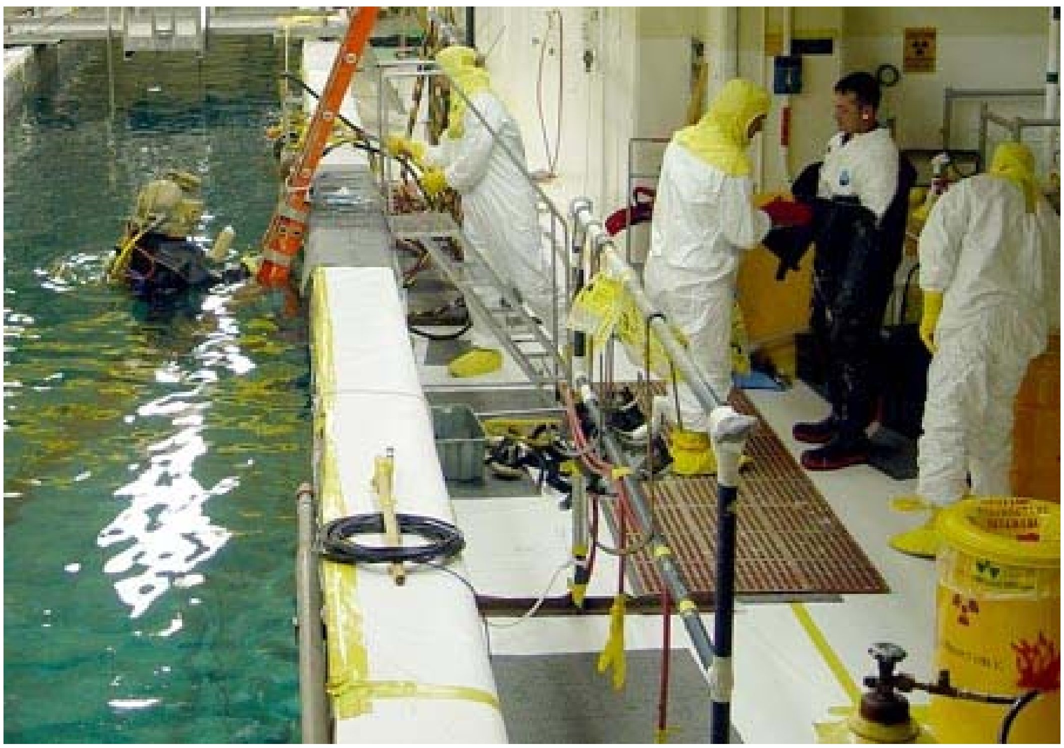


Fig. 1. Divers exiting the MTR SFP

The INL tested 14 different (mainly epoxy based) coatings to determine their conformance to SFP requirements.[3] The following criteria were used to evaluate the different coatings:

- Ease of application
- Strong adhesion to carbon steel, brick, concrete block and stainless steel
- No negative effect on water quality
- Leave no hazardous residues
- Proven in other underwater applications
- High cross-link density and pigment (to withstand radiation and contamination penetration).

The ease of application was addressed in terms of moderate, but not excessive, viscosity, application thickness and pot life. These types of coatings are used in naval applications for recoating ship hulls underwater. UES had previously made applications of one particular underwater epoxy coating in which they had high confidence. A test of that type of coating, UT-15 Underwater Epoxy (Picco Coatings Co.), determined that it was within the acceptable range of requirements for this work.

## FIELDWORK AT THE TAN-607 SPENT FUEL POOL

Fieldwork commenced in the TAN-607 SFP in the spring of 2003. The TAN-607 SFP was the largest at INL to be decommissioned in this series. Two larger pools are being placed into the D&D program and will not begin decommissioning for a few years. The TAN-607 SFP was viewed as a significant, but manageable, challenge with application to the larger future projects. The TAN-607 SFP had been used for a number of different nuclear fuels storage, with the most notable being the damaged Three Mile Island fuel and core debris (which also lead to increased contamination levels in the pool).

The first half-hour dive provided several important indications that a successful project was underway. A splash curtain was installed along the area where the diver entered and exited the water, and the entire wipe down and doffing took place within this area. The diver was rinsed off as he exited the pool, and then dried off completely with disposable wipes prior to doffing.

The radiological contamination and exposure controls were managed on a real time basis. While each section of the SFP had been extensively surveyed using remotely reporting, submersible, extended reach AMP-100 (Arrow-Tech Inc.) radiation probes, divers surveyed their work area prior to beginning work that shift. Each diver was outfitted with 5 redundant remotely reporting dosimeters multiplexed to the DMC 2000S (Merlin Gerin Co.). These instruments were integrated into the "dive station" laptop computer that monitored divers dive times. If two of the dosimeter units failed, or if dose readings exceeded the 500 mR/hr alarm set point, the diver was required to move to a lower dose area. Industrial guidelines of 3-hour dives were maintained; work below 40 feet could not exceed 1.5 hours. A team of assistants, dressed in anti-contamination clothing and a partially dressed substitute diver were maintained at the entrance to the dive at all times.

The divers averaged 5-8 mR radiation dose per dive and completed 255 dives prior to the only incidence of skin contamination. As much as possible of the sludge and any foreign objects were removed from the pool in preparation for the dives. This action, along with the shielding of the water and the heavy rubber dive suit, resulted in lower radiation doses. Debris removal was first attempted using long reach extension poles, buckets on tethers, and or placing highly radioactive objects in shielded casks. During a pre-job survey of one section in the TAN-607 basin, a highly radioactive screw head, reading 90 R/hr, (probably debris from the Three-Mile Island accident) was discovered in the area. Work was stopped until a plan could be formulated to remove the item. It was retrieved using 3 ft long tongs and placed in a stainless steel container. Work continued after this incident with a renewed emphasis on the pre-job surveys.

The process of cleaning and coating the TAN-607 SFP began with treating and cleaning the water. The diving contractor, UES, brought a multi-purpose underwater, filter/pump system (Prosser, Co, 9-50134-03X). The water was then treated with a calcium hypochlorite to inhibit algae growth. This was not particularly successful, because the water turned an opaque brown and required several days of filtration prior to diver reentry. After cleaning the water, a hydraulic hull scrubber device, like those used to clean boat hulls, was used to clean the pool walls. A large number of paint blisters were found as the wall scrubbing progressed. Every blister required additional scrubbing with a hard bristle steel wire brush, thus slowing the cleaning and coating process significantly. The next step was to vacuum the floor of the pool. The multi-purpose filtration system was used for this as well.

Fig. 2. Special two hose roller system used for wall coating

A special type of paint roller system was used for underwater application of the epoxy coating. It is shown being used underwater in Fig. 2. The system had two separate pumps for the epoxy resin and hardener, which pumped through separate hoses to a mixing manifold about 5 feet from the roller. The roller/extruder system was flexible up to that point, and like a solid wand beyond that point through to the roller head.

Unexpectedly high dose rates were encountered in two work evolutions. One occurred when a particle became lodged in the ridges of the vacuuming hose that the diver used to clean the bottom. A smooth hose was substituted so that it would be less likely that particles would become lodged in the hose. On a second occasion the knee areas of the diver became highly contaminated from kneeling in debris on the pool floor. To facilitate removal of this contamination in subsequent dives, the knees and shoes of the diver were covered with duct tape in a manner that the duct tape could be easily removed prior to the divers leaving the basin.

Another unexpected problem was instrumentation malfunction in the wet and high vibration conditions typical during this project. Condensation occurred within some of the radiation detection equipment (particularly the multiplexers). Opening the covers of the dosimeters and letting them dry overnight solved this condensation problem. Some of the wires on the electronic dosimeters were fragile and did not stand up well to the vibration and manipulations of the divers. To address this failure potential, the connection points for the dosimeters were reinforced with electricians tape at the clamp areas and all the connectors were tightened regularly.

Overall the TAN-607 SFP project was highly successful, reducing personnel exposure, schedule and cost from the baseline case. It was projected that the radiation exposure to divers cleaning the pool would be 1056 mR; the actual exposure was 744 mR. The highest dose to any diver was 196 mR, which was well below that anticipated for even a conventional, non-diver (baseline) approach. Exposure for the support personnel was projected at 200 mR, and was actually 80 mR. The project schedule was reduced by 1.5 months and the cost was reduced by $200,000 from the $1,900,000 baseline estimate.[1,4]

## DECOMMISSIONING THE DRESDEN UNIT 1 SFP

Decommissioning the Unit 1 actually began more than 25 years prior to the SFP campaign. Reactor operations had been suspended in 1978, defueling had taken place at that time, fuel and the fuel pool equipment (racks and accessories) were removed in 2002. Some cleaning had been performed in the SFP, but no campaign had been waged to completely gut the pool. When the racks were removed, they were cut off at floor level leaving protrusions as high as 4 inches. The water quality had deteriorated significantly and there was no longer any appreciable visibility below the water line.

The Unit 1 team was planning a cleanup of the SFP using long handle tools and coating the pool as the water was lowered. This is a conventional method of SFP cleanup, but poses some concerns. The primary concern with this approach was the potential of high airborne contamination from allowing contaminated poolsides to be exposed during the draindown. Another concern was the length of time involved in slowly removing water and treating the walls. The disposal of water had to be scheduled with the operating unit's (2/3) treatment system. The availability of the 2/3 system could not be assured over a wide periods of time, but could be used on a (available space and time) campaign basis.

The INL underwater coating approach was attractive to the Unit 1 team for a number of reasons. First, the INL had no airborne contamination problems during the SFP coating projects. Second, with the underwater coating option, there is little concern about scheduling for draining away the pool water; the water can be taken away at any time after the cleaning and coating is completed and does not impact the operating unit or the decommissioning schedule. This option is estimated to have less injuries from strains involved in extensive use of long handled, underwater tools. Using the divers certainly allows more successful cleaning of the pool bottom and also allows closer cutting of pool equipment (previous long handled cutting only was able to leave the

4 inch rack stubs). Of course the reduced schedule, cost and radiation dose shown in the TAN-607 SFP project was an advantage

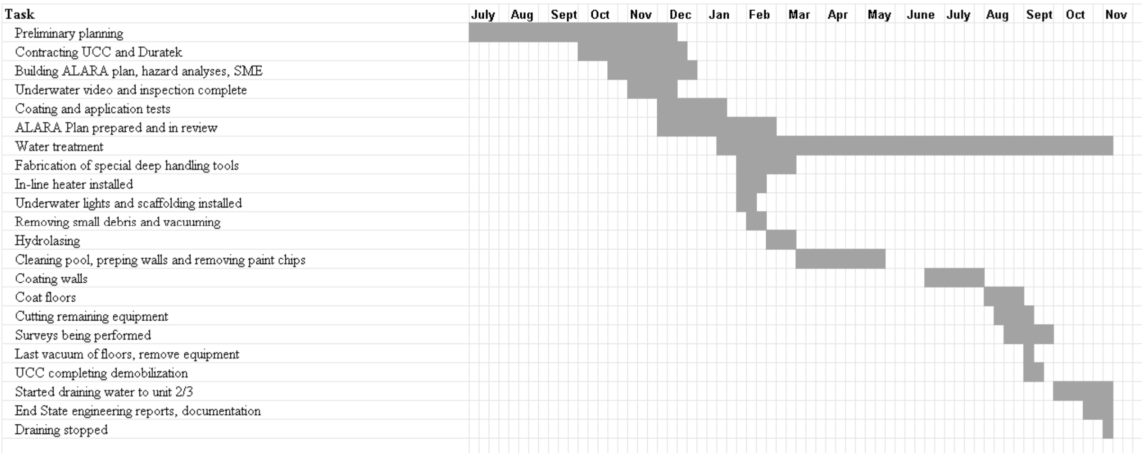
The Dresden Unit 1 SFP is designed with distinct portions that have different depths, functions and kinds of equipment. The SFP is “L” shaped with the main body composed of two separate pools, called the storage pool and the transfer area. The storage pool is 20’x 25’x 26’ deep. The transfer area is 20’x 25’ x 45’ deep. The storage pool had contained spent fuel racks that had been bolted to the floor, but were previously removed. In the transfer area, fuel could be examined, packaged and maintenance could be performed on reactor components. These two pools were connected with a gateway that could be closed between them. A transfer channel, 7’ x 15’x 59’ at the bottom of the transfer area, connected the transfer area to the reactor compartment.

Preparations for the underwater coating project began after the Exelon management had reviewed the options. The underwater option is not intuitively safer industrially and radiologically but is statistically safer and was proven at the INL. Members of the Exelon team had to be convinced that the promises were not empty. Discussions between the Exelon and INL radiological management convinced Exelon that this was the correct pathway. A different dive contractor, Underwater Construction Company (UCC), was contracted as a preferred provider in the Exelon nuclear system and was tasked with the job of underwater cleaning and coating. UCC has performed similar types of nuclear jobs involving coatings at reactors.

An underwater survey of the SFP was also a key initial activity. The pool condition and remaining items in the pool were documented from previous cleaning efforts. But a current survey and up-to-date pictures or video were not available. The INL provided their Remote Underwater Characterization System (RUCS) (essentially a small, tethered submersible), along with an operator, to provide video and radiation dose measurements. Although the RUCS system was not a calibrated Exelon unit, its dose measurements were adequate for development of the ALARA plan. The RUCS showed that the general floor had dose readings of 2-3 Rem/hr, (with hot spots up to 11 Rem/hr) but that the general pool dose was less than 10 mR/hr. The in-depth survey identified additional items in the pool not previously identified.

The Dresden Unit 1 SFP project proceeded in a logical series of tasks taking more than a year to complete. Table II below shows the series of tasks and associated schedule required to perform this work. Each task will not be discussed in detail, but some of the more interesting activities will be examined. The overall project took considerably longer than expected, primarily because of the resource drain caused by scheduled work on other reactors. Work on operating reactors always takes precedence over decommissioning work. This was manifest in the non-availability of Radiation and Contamination Technicians (RCTs). Thus, decontamination tasks that were expected to take a few months lasted an entire year.

Table II.  Task Schedule for the Dresden Unit 1 SFP Underwater Coating Project




The most extensive activity involved in the underwater coating project was the water cleanup task.  The water in the SFP required treatment for two main reasons:  there was a considerable amount of algae on the surface and the general water condition was moderately contaminated.  The bottom was not visible, and the sides of the pool were essentially invisible below the algae layer.  Since visual contact with the diver was required at all times in the SFP, no diver work could start until the water was treated and visibility was restored.  There were reasons to maintain as much cleanliness in the water as possible also.  Beyond the need for visual contact, higher cleanliness contributes to lower radiation doses and contamination on the diver's suit.  This makes the job of avoiding skin contamination much easier.  Cleaning the water also permitted the water to meet the 2/3 system requirements without further remedial treatment.

The process of cleaning the water required a considerable amount of technology.  A specialist in the field, DURATEK Co., was contracted to achieve and maintain water quality.  The first step was to "shock" the water with the addition of 10-15 parts-per-million (ppm) hydrogen peroxide.  The hydrogen peroxide primarily served to kill the algae and bacteria.  After the initial injection of the peroxide the water turned dark brown and remained this color for several weeks.  The peroxide injection system allowed the use of ultraviolet light and ion-exchange after a few days (when the algae were destroyed).

A system known as the "Tri-Nuc" Filter System (Tri-Nuclear Corp., model UFV-100) was placed in the pool to maintain long term water quality.  The Tri-Nuke is a canister type, shielded filter about 30 inches long and 7 inches in diameter.  It is a self-contained system that contains a submersible pump and is easily maintained (easy filter removal).  After the peroxide injection and 3 weeks of Tri-Nuc filter operation, the pool water became crystal clear and maintained this clarity throughout the project.  Over the course of the project, 50 of the Tri-Nuke filters were used.  A skimmer system was added to the Tri-Nuc to clear the floating algae debris.  The underwater diving contractor (UCC) brought a separate vacuum/filtering system, consisting of a pump and eight 15" filters on a manifold (Fig. 3).  This system also helped to maintain water clarity, but its primary purpose was to contain the paint chips and floor debris.  A "rock catcher" screen was used on the UCC system to prevent larger particles from going through the pump.

Fig. 3.  UCC vacuuming filtration system underwater manifold

Following the filtration and water treatment tasks the wall and floor surfaces were cleaned and prepared.  At the start of each work shift the work area was surveyed using an underwater dosimeter.  The floor surface was thoroughly vacuumed using the UCC vacuuming system.  The stubs left from previous fuel rack removal were cut with a plasma torch.  These were removed along with other small debris until the floor area was basically clean and free of obstruction.  While the walls of the INL SFPs were cleaned using the hull scrubber, the Unit 1 walls were cleaned using hydrolasing.  Hydrolasing uses high pressure water, recycled into the pool, to blast off grime and loose paint.  This was a very effective method.  Areas where the paint came off, or where blistered paint was present, were cleaned with a 3M ScotchBrite pad prior to recoating.

Several devices were used to afford easier pool access, greater visibility and diver communication.  A portable scaffolding device, much like a window cleaners or painter's work platform, was used in the wall cleaning and coating.  It was easily raised or lowered to different work levels.  Underwater lights were used to give better visibility for the divers, and inexpensive underwater cameras (purchased from a fishing outlet) were employed by the engineers to supervise progress.  Voice communication devices were installed in the divers' helmets.  Each suit was pressure tested for leaks and thoroughly surveyed for contamination prior to each dive.

The pool and cleanup equipment required some on-site modification during the course of the project.  A large water heater was brought in to raise the water temperature from about 60$^{o}$ F to 70$^{o}$ F.  This enabled more comfortable diving and ensured that the pool walls were at an appropriate temperature for proper coating adhesion. The paint flow through the system was initially slow and somewhat inefficient.  A heated "trace" line was added to the single delivery hose lines and the paint was reformulated to achieve a lower viscosity.  The most serious problem was that the mixing lines were too far from the paint roller head.  With the long mixing time for the travel of the resin and hardener through the hose, the paint began solidifying before it reached the roller.  The mix point was moved to within 4 feet of the paint roller head.  Heavy, stainless steel buckets were used to transport floor debris, like nuts, bolts and pieces of basin equipment. A long-reach pickup device was fabricated from a pair of Vice-Grips. This tool, like the long handled tongs used at the INL, was invaluable for moving radioactive items.

Two large fuel transfer fixtures were not removed from the lower level of the transfer channel during previous cleanout activities. These fixtures, called “elephants feet”, resembled large, inverted flower pots about 3’ diameter and 7’ tall. The project engineers were uncertain whether to cut the elephant feet up and remove them, or to decommission them in place and simply paint them. The final decision was to cut and remove them; thereby completely cleaning the SFP and leaving less future liabilities.

A normal dive duration was about 3 hours with two divers in the water at any time. Two dive shifts were typically performed during a workday. Divers first cleaned and coated the top ten feet of the entire fuel pool and the pool was drained down to that level. This allowed the areas below 40’ to be completed with the regular 3-hour dive limitation instead of a reduced limit of 1.5 hours (a lower dive duration limit is imposed on dives below 40’). While highly contaminated items were found in the SFP (1 to 50 Rem/hr), the working dose for the divers was 1 to 50 mR/hr due to the shielding of the water.

Several different types of waste were generated during the SFP project. Two different types of filter wastes were generated: Class A waste Tri-Nuc filters, and Class C waste underwater vacuuming filters. All filters were removed from their respective systems, allowed to drain above the pool, and air-dried. The fifty Tri-Nuc filters were placed in on-site storage. Eighty vacuuming filters were shipped off-site and compacted. Two buckets of miscellaneous parts and equipment were collected from the floor. Special radiological instructions were prepared to facilitate removing those items from the pool. One highly radioactive item was an in-core detector (fission chamber) reading about 70 Rad/hr. This item contained a small amount of special nuclear material and had to handled and accounted for separately. A 55-gallon barrel of general dirt, corrosion products and paint chips was collected from the vacuuming screens. All of the solid debris was air-dried and packaged as Class A waste held for future disposal.

The project was a success, with less overall worker time, worker exposure and no significant safety incidents encountered. It was estimated that the project would require 14,065 hours to complete, with 22 total Rem dose. The actual number of hours was 10,186 hours and only 3.59 Rem total. There were 281 dives completed with no skin contamination incidents. The water treatment systems were successful at cleaning the SFP water from out of specification levels of contaminants, algae and bacteria to within processing requirements for the Units 2/3 systems.

## LESSONS LEARNED

During both SFP projects (INL and Dresden Unit 1) a number of lessons were learned that can be shared about these projects. The most significant of these are listed below:

- Nuclear trained divers must be used for these projects. There is no substitute for trained and experienced divers. They know the proper contamination control processes for this

kind of project and most effective for difficult operations. These folks will be the key operating personnel when the work goes forward.
- High quality water treatment systems are required to attain and maintain water clarity and low contamination. This is essential to diver productivity and contamination free operations.
- Unusual objects (probably highly contaminated) are likely to be found in SFPs. Work areas should be surveyed periodically using the waterproof dosimeters. Some flexibility with special procedures and extended reach tools should be planned into the work. Simple tools like cheap cameras and Vice-Grips can be effectively employed.
- Loose and blistered paint will significantly slow the project and consume much more of the paint resources. On the INL work the delays were significant and as much as 50% more paint was required due to blistered paint.
- The RCTs and support personnel should remain consistent over the project. Choose the best people to monitor, clean and check equipment and leave them in place as a dedicated team.
- Epoxy coatings can have tricky application requirements. Ensure that the manufacturer has optimized viscosity for roller application and that temperature requirements are met. Use a two hose application system if possible.

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