Boiling Water Reactor High Flow Filter System - 15683

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ABSTRACT

Mechanical filtration is an essential element of industrial processes and operations. In the nuclear industry, mechanical filtration is particularly problematic because of the added challenge of minimizing personnel exposure and contamination associated with filter handling.

Until recently, there has been no effective filtration system to maintain water clarity and minimize dose for diving operations in Torus/Suppression Pools, or for vacuuming operations to decontaminate Dryer Separation Pits during plant outages. To be effective, the filtration system must provide high flow to speed recovery from low visibility conditions. It must also have a high dirt loading capacity to minimize downtime during outage critical path.

This paper looks at a new filtration system that has been introduced to the U.S. commercial nuclear power industry and used in numerous outages since 2012 and compares this Solids Collection Filter (SCF™) system to previous filtration systems and practices and its impact on outage diving operations and decontamination efforts.

INTRODUCTION

Historically, filtration systems have been used to clean Torus/Suppression Pools to maintain water clarity for diving operations, and to decontaminate water during fuel movement to reduce dose rates at the water surface and lessen exposure to outage crews. Unfortunately, such systems have been only marginally effective at accomplishing these tasks, and the handling of their expended filters has been both dose and contamination intensive.

What has been needed is a filter system that can handle high flow rates and heavy sludge loadings, while minimizing or eliminating the need to handle and characterize each expended filter element. Such a system would reduce labor, personnel exposure and contamination events. Over the last five years, Diversified Technologies Services, Inc. (DTS), of Knoxville, TN, a Division of AVANTech, Inc., Columbia, SC, has used high capacity filter membranes to filter water and collect solids during decommissioning support projects. These filter membranes can be used individually or ganged together in pressurized Solids Collection Filter (SCF™) canisters that hold three, five or seven membrane elements, depending on the desired flow rate.

Recently, DTS designed and fabricated an array of four SCF canisters within a standard steel disposal liner. This SCF Liner is ideal for filtration applications that involve high flow and/or high dirt loading, and where it's important to minimize waste handling and packaging.

Photo 1

Filter membranes in SCF canister (top of canister has been cut off for viewing). Note high dirt loading on depleted filters.

Photo 2

Liner pan with four SCF canisters and influent/effluent manifolds in place. The 6 inch (15.2 cm) plumbing shown is required to support operation up to 900 gpm (3.4 m^3/m).

PVC in bottom of the pan is used for dewatering, if resin is sluiced into the void space around the canisters after the filters are depleted.

The SCF Liner consists of a standard 8-120 liner (59.50 inch diameter, 69.75 inch height, 112 ft^3. Internal volume / 151 cm diameter, 177 cm height, 3.17 m^3 internal volume) with four SCF canisters inside, plumbed together with pressurized influent and effluent manifolds. While the 8-120 is perfectly sized for four canisters and is the most widely used configuration, SCF canisters can be installed in any steel liner that fits standard shipping casks, including a 14-200 liner

(74.50 inch diameter, 74.75 inch height, 189 ft^3. Internal volume / 189 cm diameter, 190 cm height, 5.35 m^3 internal volume), which holds seven canisters.

This paper looks at the initial operating experience and empirical data gathered during use of a new SCF system in commercial nuclear plants.

Photo 3

Assembled 8-120 SCF Liner with lift slings and stencils, as well as part of external inlet/outlet plumbing for operation at flow rates up to 900 gpm (3.4 m^3/m). A Grapple Ring is available to facilitate remote movement of the liner.

Previous Filtration System

In the past, filtration systems for diving operations involved a train of small filters linked together and submerged in the Torus/Suppression Pool. These filter systems were only marginally effective at maintaining water clarity when divers stirred up settled debris. Particularly troubling was the inability of these systems to recover from loss of clarity. Visibility in the water often dropped to a few inches, which sharply reduced diver productivity while increasing exposure due to longer stay times, increased number of dives and higher ambient dose rate in the water column.

The shortcomings of these systems were compounded by the need to remove and characterize each expended filter. Divers had to manually remove the filters from the pool, and operating personnel had to receive, bag, and transport them to a drop off area – all dose intensive activities. Later, these filters had to be handled again while they were surveyed and characterized in preparation for packaging, transport and disposal.

A Better Way

Since the early 2000's, DTS has provided individual SCF canisters for decommissioning projects. Each stainless steel canister contained an array of seven fixed membranes, supported 250 gpm (946 lpm) flow and heavy dirt loading, and could be used submerged or out of water. While these canisters represented an improvement in filtration technology and were very effective, they were not ideal, as they had to be individually handled and disposed of.

After testing and using the individual canisters for about 10 years, DTS determined that a better approach was to manifold an array of four of these canisters inside a steel liner that was approved for disposal in a commercial site such as the one at Clive, Utah. The key challenge was to design the piping needed to support up to 1,000 gpm (3,785 lpm) in the confined space of a steel disposal liner. It was important that this be a contained pressurized system, as any atmospheric level control system would be quickly overwhelmed at several hundred gpm. The pressurized system eliminates the need for a level control system and constant monitoring.

High Capacity Filter Membranes

The high capacity filter membranes used in the SCF canisters are available in absolute micron ratings of 2, 5 and 10. Each radial pleated membrane has 220 ft^2 (20.4 m^2) of surface area, and is rated at 40 gpm (151 lpm) with a maximum pressure drop (D/P) of 35 PSID (240 kPa).

When seven of the membrane elements are ganged together in one SCF canister, the filtration surface area is 1,540 ft^2 (143 m^2) and the rated capacity is 280 gpm (1,057 lpm). When four canisters are then joined in an SCF Liner, the total filtration surface area of this unit is 6,160 ft^2 (572 m^2) and yields a nominal rated capacity of 1,120 gpm (4,239 lpm). Pump and plumbing limitations result in a typical operating flow rate of 750-900 gpm (2,839-3,407 lpm).

As shown in Table 1, a single SCF Liner provides flow rates and dirt loading capacity many times the filtration capacity of current filter systems – at a fraction of the effort and exposure required to purchase, change out, handle, survey, characterize and package their depleted filters.

Table 1

Comparison of Filter Surface Area

Filter Type	Filtration Area per Unit			**How many needed?**		Total Filtration Surface Area	
	ft^2	m^2				ft^2	m^2
SCF Liner	6,160	572	X	**1**	=	6,160	572
Tri Nuclear Pleated Filter	60	5.57	X	**103**	=	6,160	572
8”x 20” Bag Filter	3.5	0.33	X	**1,760**	=	6,160	572
2” x 24” Cuno-type Filter	1.0	0.09	X	**6,610**	=	6,160	572

Water Filtration

The primary function of the SCF system is for high volume filtration in Torus/Suppression Pools during diving operations, and Dryer Separator Pits and reactor cavities during refueling. While the main goal of high flow filtration in the Suppression Pool is water clarity for the divers, the reduction in particulate activity in the water column is also important to ALARA. With solids and particulate removed from the column, diver productivity is increased and exposure is decreased. Likewise, decontamination of the water column during refueling can reduce exposure to refueling personnel by a factor of 2 to 5.

Solids Vacuuming

The SCF is equally effective at removing solids/sludge from Suppression Pools, Equipment Pits and sumps. The same high volume filtration system configuration used to clear water in Suppression Pools or Dryer Separator Pits can also be used to vacuum solids and debris. An inlet shroud (on the submersible pump) with cam-lock connections allows attachment of suction hoses that are typically 2 or 3 inches (5.08 or 7.2 cm) in diameter to vacuum the solids from the pool or pit, or capture particulate at the point of generation by positioning the suction hose in the immediate vicinity of the work area.. The pump inlet is protected by a screen to prevent ingestion of larger objects that might damage pump internals.

User Experience

In early 2012, Nine Mile Point Nuclear Station, consisting of 621 and 1,140 MW(e) GE Boiling Water Reactors (BWR), and Limerick Nuclear Generating Station, consisting of twin 1,134 MW(e) GE BWRs, ordered SCF Liners, pumps, controls, piping and hosing systems in support of upcoming outages.

Nine Mile

The Nine Mile project focused on vacuuming and decontaminating the Dryer Separator Pit to eliminate the need for manual decontamination of the walls and floor. DTS’ remote control

crawler system was used to vacuum the floor areas. The walls were flushed as the water level was lowered in the pit. When a few feet of water remained in the pit, a centrifugal pump was positioned on a platform above the water to provide about 60 gpm (227 lpm) suctioning flow rate for vacuuming. The vacuumed water, debris and activity were pumped up to the SCF Liner for filtration, and then the water was returned to the Pit.

The Nine Mile installation successfully decontaminated the Equipment Pit to low dose and contamination levels without having to send maintenance personnel into the pit to manually decontamination the floor and walls. Based on the reductions in exposure and manpower realized with the SCF Liner system, Nine Mile has ordered another SCF Liner for its Spring 2014 outage.

Limerick

The Limerick installation included a submersible pump placed in the Suppression Pool, with quick assembly Schedule 10 piping and fire hoses routing the process water from the pool to the SCF Liner, and then returning the filtered water to the opposite side of the pool. This created a circulation flow of 750 gpm (2,839 lpm) that directed clean water across the divers work area while sweeping cloudy debris laden water away from the divers and toward the submersible pump outlet.

During this campaign, the system ran for several hours until the liner developed an elevated dose rate in a traffic area. Because there was no way to supplement liner shielding, the decision was made to secure SCF operations. Nonetheless, the ability to rapidly improve visibility for the divers and to process large volumes of water had been demonstrated.

The partially depleted SCF Liner was placed in temporary storage for use during the next outage, when appropriate shielding could be provided. Limerick ordered an additional SCF Liner as a backup, to ensure sufficient filtration capacity to complete the Winter 2014 outage.

As shown in Figure 1, Suppression Pool water is drawn from one side of the pool, filtered and decontaminated, and then returned to the opposite side of the pool to set up a current of clean water that flows across the diver work zone, improving clarity and reducing ambient dose. Vacuuming of debris is achieved by hooking suction hoses to the inlet pump shroud.

The SCF remained in continuous operation during the 9-day outage (3/16/14 – 3/25/14), and processed 5,586,000 gallons (21,145 cm3). The dive teams ran three separate desludging pumps, the discharge of which was directed by hose to the inlet suction shroud of the SCF submersible pump with no degradation of water clarity.

During the dive window, visibility was a minimum of 3 feet (0.91 m), and most of the time was 8 – 12 feet (2.44 – 3.66 m). In previous outages, visibility was often 18 inches (0.45 m). Most importantly, visibility was maintained during LOCA/LOOP pump runs.

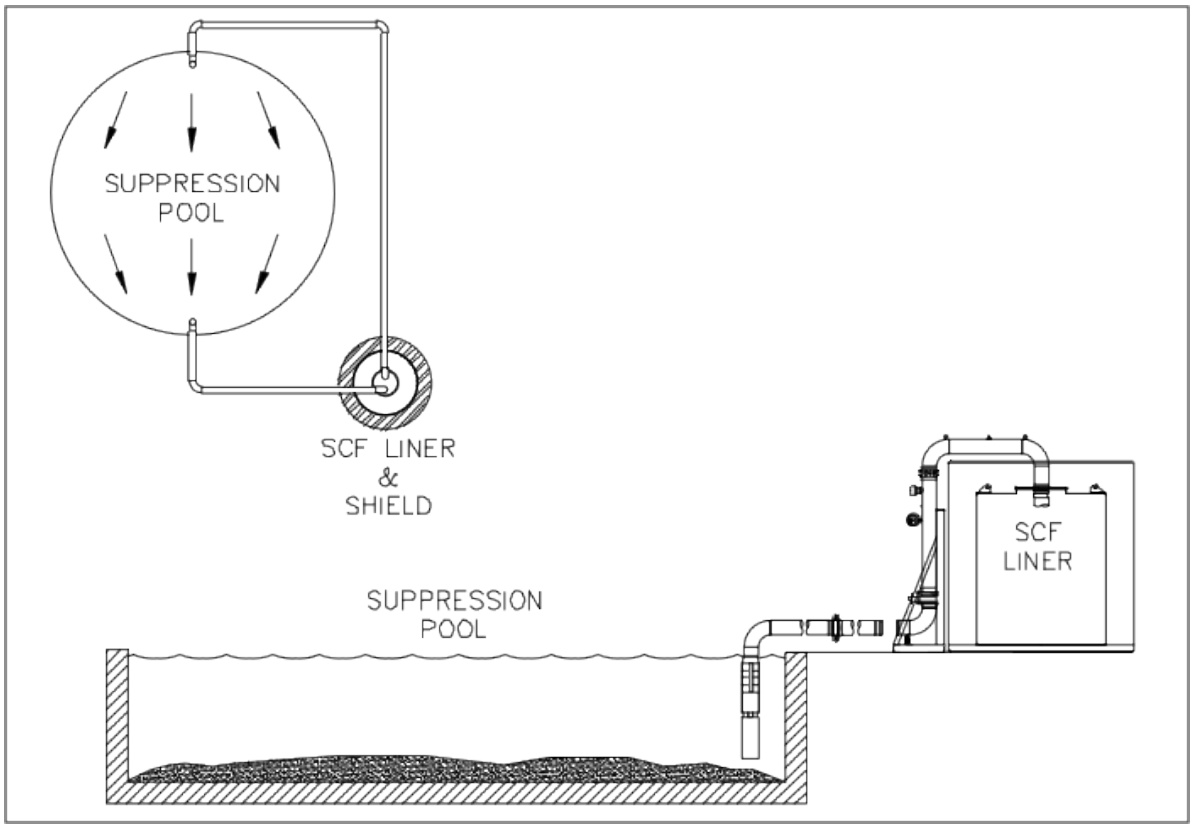

Figure 1
Typical Suppression Pool Configuration

Limerick's experience was typical of SCF installations for diver support in a Suppression Pool. Based on experience in previous outages, Limerick set a goal of 6.277 Rem (62.77 mSv). The actual incurred dose was 2.687 Rem (26.87 mSv)-- a savings of 3.59 Rem (35.0 mSv). Of this, approximately 2 Rem (20 mSv) was saved by eliminating the manual handling of 60-80 diver canister filters in the Suppression Pool. Another 0.5 Rem (5 mSv) was saved by the reduced dose rate to the divers, and the need for fewer dives. The total dose to the divers was the lowest ever achieved at Limerick.

Cooper

In Fall 2012, Cooper Nuclear Station, a 758 MW(e) GE BWR, used the SCF system during its RE27 outage. The configuration used to clean Cooper's Suppression Pool was similar to that used at Limerick. In this campaign, a single SCF Liner removed more than a quarter ton (254 kg) of solids during vacuuming operations, and clarified water for diving. Diver visual range was improved, and exposure to personnel was reduced by eliminating filter handling. When the project was complete, Cooper stored the pump and plumbing on site. For the most recent October 2014 outage, Cooper used a larger (14-200) SCF Liner, with seven SCF canisters, which maintained high flow rates during outage diving operations.

LaSalle

LaSalle County Generating Station, with 1,118 and 1,120 MW(e) GE BWRs, was the first user of the SCF system under a new Exelon fleet contract. In January 2014, in support of the L1R15 outage, DTS provided a 20-hp submersible pump, Schedule 10 quick assembly piping, two 50 ft. (15 m) suction hoses, and an SCF Liner with piping, controls and instrumentation, return line and discharge diffuser. This system was installed in the Dryer Separator Pit.

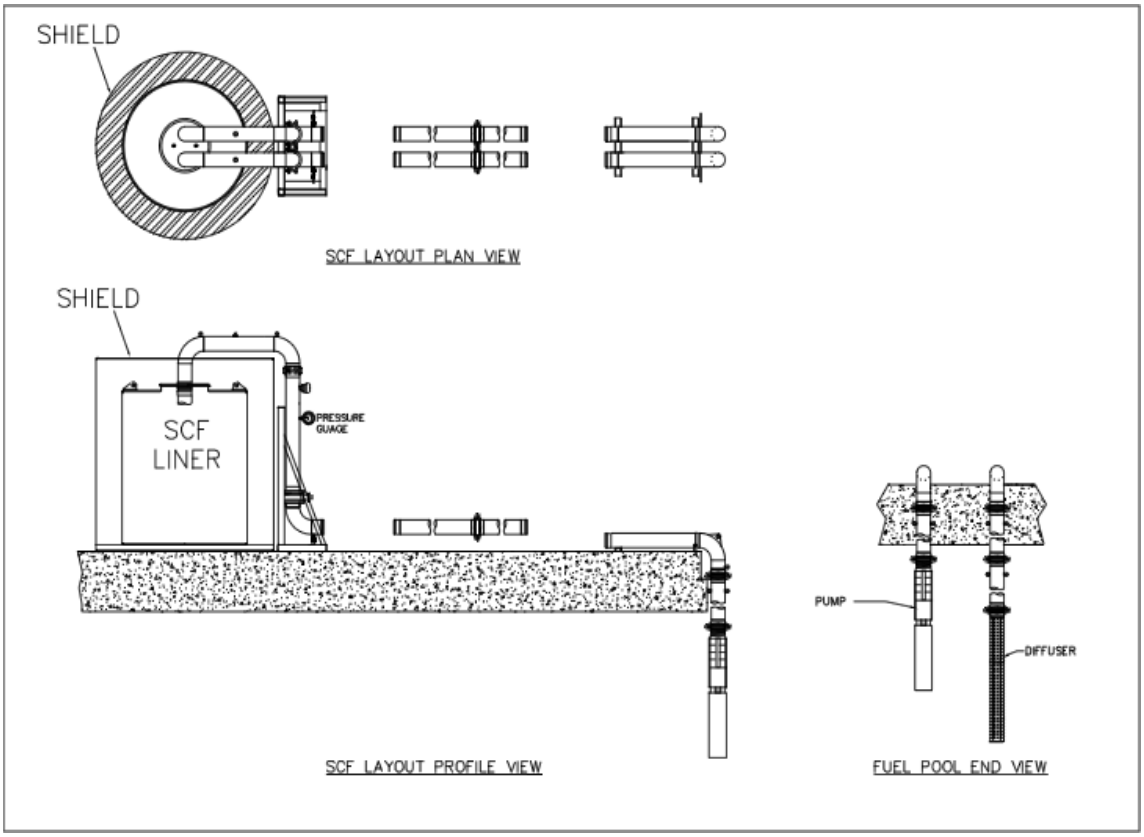

Figure 2
Typical Dryer Separator Pit Configuration

Figure 2 illustrates a typical Dryer Separator Pit installation. The purpose of installing the SCF system in the Dryer Separator Pit is to effect high volume water filtration to maintain water clarity and, more importantly, to filter and capture particulate dislodged during refueling operations. Historically, disturbed radioactive particulate in the water column elevates surface dose rates which, in turn, results in increased exposure to refueling crews. An ancillary benefit is reduction of particulate contamination of pit walls and surfaces.

Outage tasks included general vacuuming, vacuuming of guide tubes, operating a submersible remotely operated vehicle (ROV) and cavity vacuuming. These activities were supported by a customized inlet shroud installed on the submersible pump, which provided two 3 inch (7.62 cm) and one 2 inch (5.08 cm) cam-locks to connect various suctioning and vacuuming hoses. This permitted 50 foot (15 m) suction hoses to be positioned in the immediate vicinity of the work

area during movement of equipment and fuel, to capture crud and debris at the source instead of allowing the activity to be dispersed throughout the water column.

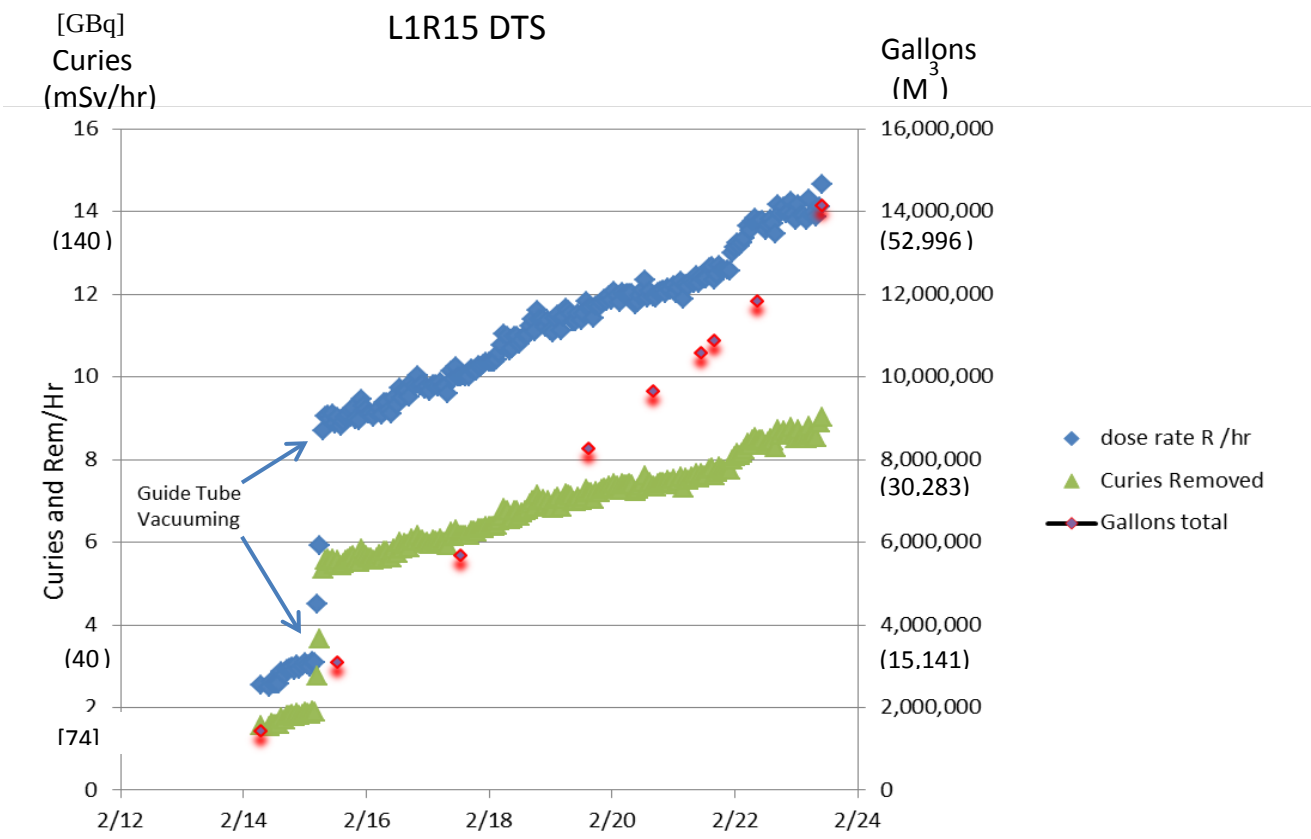

Figure 3
SCF Performance, LaSalle 2014 Outage

The same SCF liner and pump system was used to support the LaSalle Unit 2, mid-cycle maintenance outage (L2M17) for water filtration in May 2014. During the 4 days of SCF operations, an additional 2,600,000 gallons (9,842 m^3) of water was processed for a total 16,600,000 gallons (62,838 m^3) through the SCF liner; the equivalent of 22 pool turn overs.

The results of the second campaign, Figure 4, shows an additional 5.4 Curies (200 GBq) were removed and dose on the liner increased from 14.6 Rem/hr (146 mSv/hr) to 24.5 Rem/hr (245 mSv/hr).

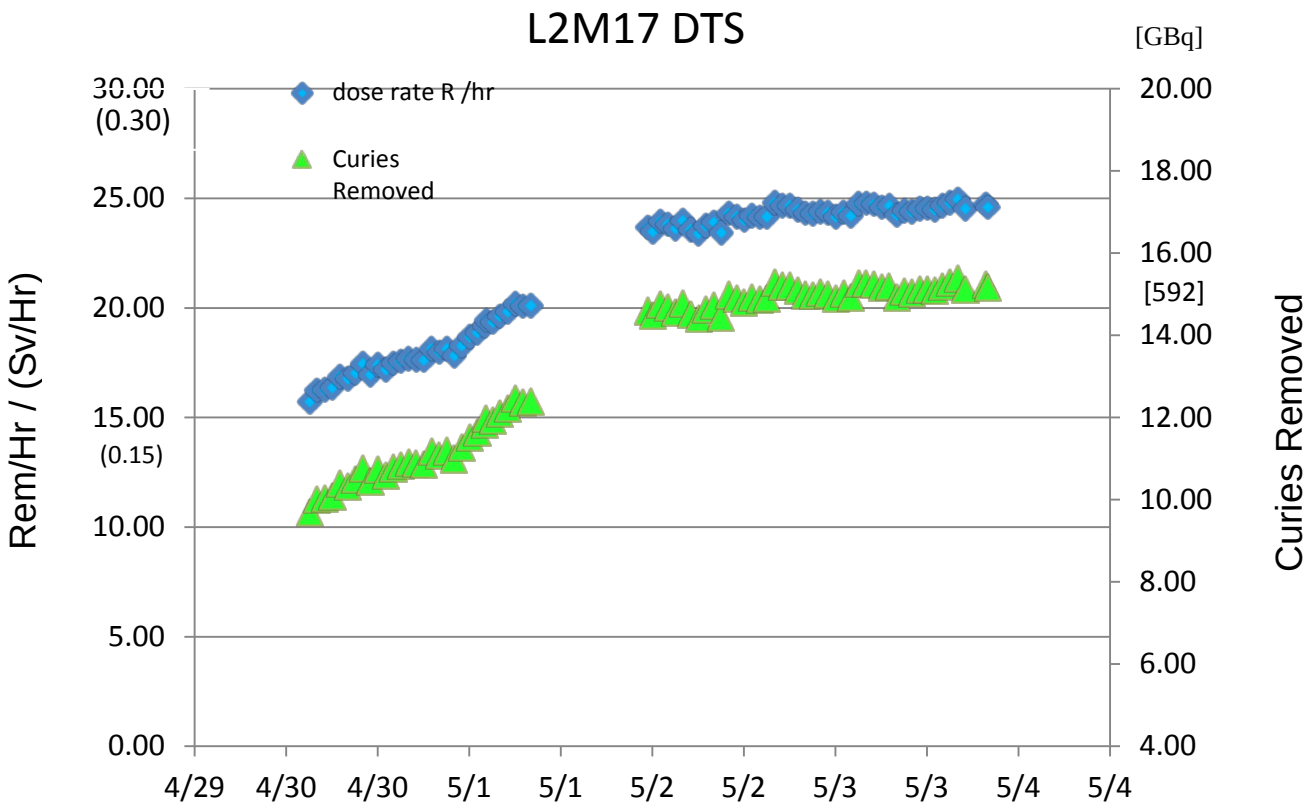

Figure 4
LaSalle Mid-Cycle Outage

The effectiveness of this source capture strategy was proven in reduction of water surface dose rates. In similar outages, the water surface dose rate would spike as high as 12-15 mRm/hr (0.12-15 mSv/hr). Using the SCF system source capture strategy, the peak surface dose was <2 mRm/hr (0.02 mSv/hr), which resulted in reduced dose to refueling personnel. At the completion of the outage, surface contamination levels were also sharply reduced, with an overall savings of 2 Rem (20 mSv) -- the best ever on LaSalle Unit 1. The sharp increase in curie collection and dose rate on 2/15/14, as shown in Figure 3, was associated with vacuuming the guide tubes.

Fukushima

Diversified recently provided SCF liners to support the Kurion Fukushima strontium removal systems. The SCF liners filter process waters ahead of the Kurion ion exchange to remove particulate from the process stream which could foul the ion exchange bed. The permeate from the 2.0 micron absolute SCF liner flow through a similar 8-120 liner fitted with ultrafiltration (UF) modules to remove sub-micron insoluble isotopes followed by the downstream Kurion ion exchange system which is primarily designed for removal of soluble isotopes.

To date 120 SCF and UF liners have been delivered to Kurion for use in its Fukushima water processing systems.

Packaging and Disposal Considerations

Packaging Efficiency and Dose Mitigation

During system operations, the void space between the canisters in the SCF Liner can be filled with water to provide additional shielding for the canisters. When operations are completed, the packaging efficiency of the depleted SCF Liner can enhanced by filling this void space with depleted resin. An underdrain system permits dewatering of the resin sluiced into the void space. Filling the void space with resin ensures compliance with the disposal site 85% fill requirement.

SCF Liner Characterization and Classification

DWJames and Associates performed the waste characterization and classification of the Cooper and LaSalle SCF Liners, which were subsequently buried at Clive, Utah. The two SCF Liners from Nine Mile were processed through the DTS facility (located within Toxco's licensed facility in Oak Ridge, Tennessee) to ensure compliance with the 85% fill and requirements and Free Standing Liquid (FSL) requirements. These characterized and classified liners were also buried at Clive.

All of the SCF Liners were well within Class A limits, as expected, given that their primary filtration target was cobalt. Nonetheless, each user must independently assess the final projected classification based on the unique source term of his/her plant. It should be noted that the SCF Liners are also approved for disposal at the Waste Control Specialists' facility in Andrews, Texas, should the final Waste Classification exceed Class A.

SUMMARY

The DTS Solids Collection Filter (SCF) system has a demonstrated track record of providing high flow (700-900 gpm, 2.65-3.4 m^3/m) and high solids removal capacity (>500 lbs., >254 kg/liner) to maintain water clarity for diver operations. In this application, exposure to personnel is minimized by reducing activity in the water column of Torus/Suppression Pools, and by eliminating filter handling.

The SCF system is also effective at filtering millions of gallons of water during refueling activities, and collecting source point solids to reduce distribution of activity into the water column, thus reducing exposure to refueling personnel. Contamination levels of pit floors and walls are similarly reduced.

The SCF can be used in conjunction with a remotely operated crawler to vacuum and decontaminate Dryer Separator Pits, which reduces or eliminates the need for personnel to enter the pit to manually decontaminate the walls and floor in order to prevent airborne contamination when the pit is drained and its surfaces are dry.

To date, all SCF Liners have remained Class A, and expended liners have an approved disposal pathway to either the EnergySolutions Clive disposal facility in Utah or the Waste Control Specialists facility in Texas.