AVANTech's Desludging and Water Processing Efforts in Support of the Enrico Fermi Power Plant 2 Torus Recoat Project – 21224

Mark Ping *, Larry Beets *, Robert Denne *
* AVANTech, LLC

ABSTRACT

This presentation describes the systems employed in support of dive operations to desludge the torus at the Enrico Fermi Power Plant 2, as well as the systems AVANTech employed to clean, store, and return over 1,892,700 L (500,000 gal) of water to the torus after a complete torus inspection and recoat. The Enrico Fermi Power Plant 2, located in Newport, Michigan, was one of several plants mandated by the NRC to perform this work before allowing continued operations.

This presentation discusses the unique combination of equipment used to achieve success, including AVANTech's Solids Collection Filter Top-Loading (SCFT™ [a]) Canister System, Temporary Demineralizer System, and Torus Water Management System (TWMS) Interface Components. It also discusses the unique challenges the project faced, including the relatively short time available to plan, design, fabricate, and deliver the equipment and personnel; the much higher than expected dose, contamination, and volumes of sludge removed from the torus; recovery from unexpected levels of total organic carbon (TOC) within the storage bags; and the challenges faced due to the COVID-19 pandemic.

With the knowledge that several other plants will need to perform this work, it is a goal of this presentation to provide those plants with valuable insight into planning so that any similar challenges can be mitigated.

INTRODUCTION

The Enrico Fermi Nuclear Generating Station is a single unit, General Electric Type 4, BWR with a Mark I containment. The plant is located in Newport, Michigan, about halfway between Detroit, Michigan, and Toledo, Ohio, on the shore of Lake Erie. Construction began in 1972 with commercial operation beginning in January of 1988.

DESCRIPTION

Pre-Outage Activities

AVANTech was made aware of the project in early August of 2019. A walkdown of the project was initiated in early September of 2019. Discussions included torus water chemistry data, past desludging efforts and weight, and dose rate expected on the removed sludge. All indications were that AVANTech needed to plan for about 17 Kg (38 lbs) of sludge with a dose rate of 7-9 Rem/hr contact. Space limitations were also a serious concern, so based on the available information, AVANTech settled on a design that included two, 208-L (55-gal) sized top loading, SCFT™ canisters with about 8.89 cm (3.5 in.) of lead-equivalent shielding.

---

[a] SCFT™ is a trademark of AVANTech, LLC.

Fig. 1. Reactor Building, SW Basement, Torus Filtration Setup

AVANTech has been providing filtration systems in support of torus/suppression pool cleaning and inspection at various nuclear power plants for over a decade. The Fermi project presented some unique challenges to the normal way of filtering pool water, which typically would include a high flow submersible pump capable of 1,893-2,839 lpm (500-750 gpm) and a set of fully contained filter canisters inside a 3.4 m³ (120 ft³) liner inside a shielded cask with 15-cm (6-in) supply and return lines. The challenges included:

- Lack of adequate space for the normal system – AVANTech had to be able to fit the filtration part of the system in the southwest basement of the reactor building (Residual Heat Removal (RHR) quad.
- The need to run hoses across the top of the torus from the northwest hatch to the southwest vent duct, as well as back to each of five building sumps – Over 975 m (3,200 ft) of hosing was manufactured, tested, and installed for this portion of the project (normally the hosing would have run in and out of the northwest hatch).

Although AVANTech had used all the pieces for the Fermi-supplied system in different applications, time constraints due to manufacturing and item lead times put a serious strain on resources. The system chosen for the desludging portion of the operation was based on the following information provided by Fermi plant Chemistry, RP and Radwaste, and was based on both historical and actual data, which included torus water activity of 8.1 e-4 μCi/cc, solids content of 17 kg (38 lbs), and dose rates of 7-9 Rem/hr on the final collected solids. AVANTech had worked with the contracted dive team, Underwater Engineering Services Incorporated (UESI), in many past torus cleanings and were aware of how best to interface with their operations.

Planning for Desludging

For the desludging portion of the operation, the following equipment and arrangement were chosen:

- Two, 10-hp submersible pumps to connect from the discharge of the diver's pumps (5-hp Prosser pumps), to the inlet of these submersible pumps. One pump would be stationed in torus bay 14 (near the northwest hatch) and one in bay 6.
- Discharge and return hosing from each pump through the northwest hatch, across the top of the torus, through the southwest basement quad ventilation duct to and from the canisters.
- Two SCFT™ canisters placed in specially designed shields (Nuclear Power Outfitters – Eichrom Technologies, Inc.), with inlet and outlet valving manifolds and piping.

AVANTech was also challenged with supporting the filtration of torus water for drain down of the final 30 cm (12 in) to dry. Because the submersible pumps would not operate at this level due to loss of suction head, it was agreed that water and any minimal remaining sludge would be pumped to bays 12 and 13 to AVANTech air-operated diaphragm (AOD) pumps, through the system hosing out of the northwest hatch to the shielded canisters in the southwest quad, to two additional AOD pumps and to one of five reactor building sumps to Radwaste.

Planning for Bulk Torus Water Removal, Treatment, and Storage

AVANTech was also made aware that a plan was being discussed to move a significant amount of torus water to outside storage. AVANTech was presented with the challenge of cleaning that water, at a rate of 1,893 lpm (500 gpm), to ensure outside Technical Specification and Updated Final Safety Analysis Report (UFSAR) limits were not exceeded, as it was placed in outside storage. The system developed would also supply the pumping method to return that water back to the torus at the same rate. Water, with solids removed through desludging, would travel out of the torus through both TWMS pumps, through AVANTech-supplied valving, piping, and hoses, to an AVANTech Water Processing System (WPS), to outside, 378,500 L (100,000 gal) capacity bladder bags placed in a berm designed to hold the contents of those bags, as well as to the Condensate Recycle Tank (CRT)/Condensate Storage Tank (CST). Return of the water to the torus would be through an AVANTech pump designed to handle at least 1,893 lpm (500 gpm) flow.

For this phase of the project and due to time limitations, AVANTech would modify an existing 6.1 m (20 ft) cargo container housing pumps, piping, and vessels designed to move water at about 378 lpm (100 gpm), to a system that would accommodate flow rates as high as 1,893 lpm (500 gpm) or higher. The pump chosen for return of the water to the torus was a Gorman Rupp, self-priming centrifugal pump. As with the desludging portion, all the systems employed by AVANTech have been used in other configurations and were 'pre-engineered' to be able to fit in arrangements such that planned for Fermi. The AVANTech portion of the system would be as follows:

- Piping, pressure relief and pressure control valves, and hosing between plant piping and the WPS cargo container;

- A WPS cargo container with isotope selective media loaded in six, 1-m³ (36-ft³) vessels (enough capacity to treat approximately two times the 1,892,706 L (500,000 gal) of water requested to be processed);
- Piping, valving, and hosing to the bladder bags in the outside storage berm;
- Piping, valving, and hosing for return of the water to the plant through a Gorman Rupp, self-priming centrifugal pump.

Proposals for all activities, including 24/7 outage support coverage, were developed and presented, and award was made in late November. AVANTech contracts would run through Day and Zimmermann (D&Z). A very aggressive delivery date of mid to late February 2020 was established, and once a purchase order was obtained, fabrication began in early December 2019.

Long lead-time items and an aggressive delivery schedule were a challenge. On top of that, Fermi outage management asked that the equipment be delivered sooner than originally requested with a goal of having everything on site, installed, and ready to operate by the end of February. The outage start date was March 21, 2020. AVANTech was able to complete fabrication and delivery approximately two weeks prior to the original delivery date.

A major delivery challenge was in the area of security inspections. An independent security inspection team was hired by Fermi and sent to the AVANTech fabrication facilities in Tennessee. Due to the size and configuration of the equipment, not all of it would fit inside a closed, sealable container such as a cargo container or hard-side van. This necessitated the individual tape-sealing of every potential opening on the equipment and resulted in nearly a hundred security seals that had to be documented and verified on the receipt end at Fermi.

All equipment was delivered ahead of schedule.

In summary, AVANTech provided three distinct systems:

1. Torus SCFT™ Cleanout System – Responsible for support of desludging activities and final drain down of the torus from approximately 30 cm (12 in) to dry.
2. Water Processing System (WPS) – Responsible for dissolved radioactivity reduction through ion exchange, and movement of the water to the storage locations (outside bladder bags, CRT/CST, Hotwell, etc.)
3. Torus Water Management System (TWMS) – Responsible for movement of water stored in the bladder bags back to the plant (torus).

DISCUSSION

Installation and Testing

AVANTech was subcontracted to D&Z for the Fermi project and acted in an advisory role during the installation of the system. As is often the case, measurements taken and drawings reviewed may not be as accurate as hoped, so several things were employed to assist in making sure connections could be made between plant systems and AVANTech equipment without having to refabricate delivered items. Flexible hosing, where practical, is very forgiving in making up even large distance errors, especially if spare hosing is incorporated. Height adjustable spool pieces were critical in the installation of the equipment and were designed to make up as much as 10 cm (4 in) of height difference.

Most difficult was the transition from the torus water surface, to the hatch, across the top of the torus, through the vent duct, to the shielded canisters and back. Detailed drawings with hose and item identification, both on the drawings and the hosing and items, were critical to ensuring that system flows would be in the designed direction. D&Z craft were well versed in reading drawings and required little supervision in laying out the system and making connections. D&Z and AVANTech independently performed a thorough walkdown of the system prior to filling and leak testing.

Where isolation was possible, a leak test on all components was successfully performed using plant system service pressure.

Operations

System operation responsibilities were as follows:

- All pumps and valves within the torus proper – contracted dive company, UESI, and their subcontractor, Champion USA.
- All pumps and valves associated with draining the torus, except for those within the AVANTech WPS cargo container – Fermi Plant Operations
- All pumps and valves outside the torus proper associated with torus desludging activities – AVANTech Operations personnel
- All valves inside the AVANTech WPS cargo container – AVANTech Operations Personnel

Desludging Diver Support Activities

The AVANTech canister filter system in use for over a decade has eliminated the need for separate, in water cartridge filters in many applications including torus/suppression pool, fuel pool operations, and floor drain, sump, and tank cleanouts. Because personnel do not have to handle individual filters, overall dose is significantly reduced as is the resultant debris and contamination that invariably falls off the filters as they are moved in and out of the water. The canisters allow for high flow and can be shielded away from dive or fuel pool operations, thus helping reduce overall project dose and contamination.

AVANTech used their 208 L (55 gal) drum-sized, fully contained SCFT™ canisters that were capable of holding at least 91 kg (200 lbs) of sludge each. These canisters were placed in specially designed shields with approximately 9 cm (3.5 in) of lead equivalence with a goal of keeping dose rates less than a high radiation area around the shielded canisters.

The pumping system consisted of two, 10-hp underwater pumps that acted as booster pumps to the two diver-provided pumps (5-hp Prossers). Total system flow was just over 1,136 lpm (300 gpm) to start and closer to 852 lpm (225 gpm) towards the end as the filter loading increased. Ideally, the system would have been allowed to run even without divers in the water or in the torus proper, but the divers requested (for safety reasons) the motor starter panels for the underwater pumps be inside the torus. These pumps would be shut off when no tender was present. This resulted in significantly less torus water turnover through the filters than would normally have been seen had control of the motor starters been left to AVANTech. A second option would have been to place the motor starters in a more accessible area for emergency shutdown.

The filter canister shields allowed for the insertion of AMP-100 probes through the top of the shields to rest on the top of the internal canisters. Dose rates on day 1 of the project remained less than 2 Rem/hr. By the end of dive operations, dose rates on top of the canisters were around 12 or 13 Rem/hr.

Watching the diver cameras, it was easy to see that this increased and unexpected dose came from more aggressive hydrolasing activities releasing pockets of high activity and dose from blistered paint and from the down-comers.

Fig. 2. Computer Monitor Screen Shot of Torus Prior to Blasting

Movement of Water to Storage

AVANTech modified its WPS cargo container to accommodate the movement and cleaning of the anticipated 8.1e-4 μCi/cc water from the torus to the outside bladder bags and the CST/CRT. The WPS cargo container was designed to capture torus water activity prior to that water going to the bladder bags for storage outside of the north side of the reactor building. The bladder bags were housed in a specially designed berm to handle 110% of its designed capacity.

Fig. 3. Torus Water Storage Post-Filtration

As noted above, AVANTech designed this part of the system to capture water with an activity of 8.1e-4 μCi/cc. Calculations indicated that no more than about 24 mRem/hr at 30 cm (12 in) from the outside of the cargo container housing the vessels would be encountered. The system was designed so that there was enough resin available to allow for processing of well over 3,785,000 L (1,000,000 gal) of torus water at the Chemistry-specified activity. Approximately 1,968,400 L (520,000 gal) went through the system and out to the bags and to the CRT/CST. Because it was expected that nearly all the particulate would be captured in the first phase of the operation (diver non-abrasive cleaning), there was no mechanical filtration designed into the WPS system either before or after the ion-exchange resin vessels. To minimize weight during transport and maximize processing capabilities, the WPS cargo container had no added shielding in its design. The cargo container could have supported the addition of shielding on its outer surface once installed in the plant. The plant opted to install shielding on scaffolding, exterior to the container.

Fig. 4. WPS System Manifold System

As water levels were being lowered in the torus, personnel were washing down the sides of the torus, with that water then being sent through the TWMS system to the vessels and out to the bags. As more and more water was sent from the torus to the bags, dose rates on the resin vessels began to climb significantly above what was initially expected. Final vessel dose rates were on the order of 600 to 1,000 mRem/hr on contact.

Fig. 5. WPS Ion Exchange Vessels

Final Drain Down of Torus to Dry

The canisters were again used to filter water from the final 30 cm (12 in) level in the torus to Radwaste, this time using AOD pumps capable of producing flow rates of up to and greater than 378 lpm (100 gpm) total. These pumps were operated at a much lower flow rate to avoid overflow of the sumps being used. It was during this final pump-down phase of the project that dose rates on the canisters at least doubled to nearly 30 Rem/hr. Because of the high activity from paint chips and other solids found in the two TWMS drain elbows, AVANTech has no doubt that a significant amount of solids made it the WPS mixed bed resin vessels, causing significantly higher than expected dose rates on that system. That system is discussed below.

Final canister solids weight and activity is still being determined at this writing.

System Delays

Two things happened that caused delays in the movement of water out of the torus through the WPS:

- A failure of one of the vessel laterals allowed resin to escape that vessel and be captured by a mechanical resin trap prior to exiting the WPS cargo container. The mechanical trap performed as designed. After a long period of trouble shooting, it was determined that the dewatering laterals in ion exchange vessel 1 had been breached. That vessel was isolated from the system. Because the system was conservatively designed, the loss of one vessel had no major effect on the overall water quality produced. It is AVANTech's opinion that the breach occurred during transport of the cargo container from Tennessee to Fermi. Had the breach occurred prior to that, it would have been discovered during the loading of resin in the vessel. The resin was loaded in the vessels by vacuuming. Had the vessel laterals been damaged at that point, resin would have come right back out as it was being put in. Overall delay due to the failure of the vessel laterals was approximately 36 hours.

- Drain-down was started using one of the TWMS pumps at approximately 946 lpm (250 gpm). The other TWMS pump was tagged out. When the second TWMS pump was started, flow rates of 1,893 lpm (500 gpm) were expected but not achieved. It was discovered the AVANTech-installed pressure control valve spring was only rated for a maximum of 18 kg (40 lbs) instead of the designed 5-10 kg/cm (75-145 psi). Because the second TWMS pump was not available during the first five hours of drain-down, the actual delay due to the improper pressure control valve spring was about 12 hours.

Transport (out of TB-1) and Sluicing of Cargo Container

Because of the high dose rate on the vessels and the WPS cargo container, significant pre-planning and pre-job briefing was necessary to ensure the cargo container could be moved from TB-1 to Radwaste in an ALARA manner. Maintaining personnel distance was probably the most successful ALARA tool used in the move. Any shielding that was around the cargo container had to be removed prior to transport. Because air pallets were being used to move the cargo container out to an awaiting crane and trailer, any aggressive/fast movement of the cargo container could have caused it to float off the track laid down and into the gravel. Once in the gravel and depending on how far away from the crane it was, the weight of the cargo container would have prohibited the use of most standard cranes due to the excessive boom length.

Sluice operations went well due to the experience of both the AVANTech and DTE contracted senior technicians. Experience at sluice operations was key to removing nearly all of the media and the associated dose rate. Vessel dose rates, post-sluicing, were less than 1 mRem/hr on contact or essentially background.

High TOC in Bladder Bags

Upon sampling of the bladder bags in the berm, it was discovered that the water in the bags exhibited high levels of TOC. The path of the water from the torus to the WPS cargo container, to the bladder bags, then eventually to the CRT, ruled out any contribution from the WPS cargo container since levels of TOC in the CRT (the last place water went) were not high.

AVANTech was consulted about redesigning the WPS system to lower the TOC to acceptable levels. AVANTech reloaded the ion-exchange vessels with Granular Activated Carbon (GAC)/Mixed Bed media mix (80:20 Ratio), designed to lower TOC concentration in the water. Fermi had ordered a spare shield and canisters in case they were needed for desludging operations. This spare canister and shield were added downstream of the WPS cargo container to capture any non-dissolved solids that most likely were still in the water in the bags. As previously discussed above, because the original system was designed to remove dissolved solids, there was a high likelihood that some undissolved solids made it to the bladder bags. To ensure the most efficient contact time with the carbon media, the water was processed from the bags to the CRT at a rate of between 454 and 492 lpm (120 and 130 gpm) using the berm-installed AVANTech 1,893 lpm (500 gpm) pump with the bypass/recirc line open to limit discharge flow. The flow path was bags, through pump, through WPS cargo container carbon vessels, through SCFT™ canister, to the CRT.

The system worked as designed and lowered the levels of TOC from 1,000-1,200 ppb to a final level average of about 120 ppb.

System Improvements (Hindsight is 20/20)

As noted above, the key to torus/suppression pool cleaning is constant filtration at high flow rates. AVANTech would normally accomplish this using a 30-hp submersible pump with 15 cm (6 in) inlet and outlet hosing/piping with a set of canister filters housed in an 8-120 size liner inside of a shielded cask to accommodate that liner. These installed filter canisters could handle nearly 454 kg (1,000 lbs) of sludge. Time and space constraints prohibited the use of this system. Ideally, the shielded cask with filter liner would have been placed on RB-1 either in the airlock or just inside the building as close to the northwest hatch as possible. The pump and inlet/outlet lines would have been run into the torus through the northwest hatch.

In order for this configuration to work, control rod drive (CRD) moves would have had to be delayed until the divers were out of the water and pump-down had commenced. Nearly all the solids would have been removed at the high flow rates provided by the system resulting in the following benefits:

- Minimum residual solids making it through the TWMS system to the WPS cargo container vessels,
- Significantly lower dose on the WPS cargo container vessels,
- Virtually no solids making it to the bladder bags, and
- Significantly lower dose to workers during the coatings removal phase of the project.

COVID-19 Impacts

COVID-19 began to significantly impact the project around the time of the outage start. The pandemic put a strain on all resources, not just in numbers of personnel, but in the area of experienced personnel. The virus did not discriminate between experienced and non-experienced workers, and the site was often left without an adequate number of seasoned workers to oversee and perform critical activities.

AVANTech personnel remained largely unaffected until around the time of final drain-down when the most senior supervisor became symptomatic. The greatest effect on AVANTech personnel was due to the outage being extended as a result of many factors including, but not limited to, the effects of the virus on outage personnel.

Bug Impacts

The outage was supposed to have been completed long before the onset of mayfly season, but that didn't quite happen.

Fig. 6. Mayflies on Pickup Truck

CONCLUSION

Two of the most restrictive elements in planning this job were time and space. Most plants have well over a year to plan this operation; AVANTech was brought into the game roughly six months prior to outage start, and by the time a system was agreed on and delivery of equipment was expected, the timeframe was down to about three months.

AVANTech's pre-engineering, decades of experience, list of approved vendors, and a small production shop atmosphere that allows most manufacturing to occur in-house, gives the advantage of being able to put systems together quickly and efficiently.

AVANTech operators also have the experience of using the supplied equipment in many different configurations and understand how the equipment will act in the applied situation and respond accordingly before there are problems.

AVANTech's small shop does most of the manufacturing and testing in-house and can respond to spare equipment needs significantly quicker than most vendors, as was shown on this project. Spare parts can be manufactured, tested, shipped, and arrive on site in most cases in under 24 hours.

This project was not without its challenges and mistakes. However, overall performance met or exceeded expectations. AVANTech was offered the opportunity to assume tasks not originally planned for and was able to deliver on those opportunities. AVANTech responded honestly and well and has implemented process changes that will ensure even greater success on future torus recoat projects.