Davis-Besse Water Processing System Upgrade-19654

James L Braun
President and CEO
AVANTech, Inc.
2050 American Italian Way, Columbia, SC 29209
(803) 780-3844

ABSTRACT

This paper looks at the in-house liquid radwaste (LRW) processing system configuration at Davis-Besse Nuclear Power Station in Oak Harbor, Ohio. The suboptimal performance of that system, which had been in service for over three decades, prompted Plant Management to canvass the industry for LRW processing technologies and techniques that might offer improvements. The goal was to upgrade water processing performance at Davis-Besse, particularly during outages, when water generation is high and the most difficult to decontaminate water is produced.

This paper reviews the goals established by Management to guide the selection of technology and equipment components. The chosen vendor would be responsible for designing a system that would incorporate the plant's existing equipment as much as feasible, while respecting the limited space and funding available for the project.

The LRW processing system changes eventually made by Davis-Besse are identified and discussed. We also offer a summary of pre- and post-upgrade operation and performance in vital areas, including manpower requirements (for operation and maintenance), effluent quality, waste production and overall operating cost.

The information and experiences cited in this paper are directly applicable to other nuclear power plants who might contemplate an upgrade of LRW processing systems or of individual system components.

Davis-Besse Background

Davis-Besse Nuclear Power Station is a Babcock & Wilcox 908 MW nuclear power plant located northeast of Oak Harbor in Ottawa County, Ohio, U.S., approximately 25 miles east of the city of Toledo. Construction began in September 1970 and began operation in 1977. It has a single, 984 MW, pressurized water reactor.

Davis-Besse is owned and operated by FirstEnergy Nuclear Operating Company (FENOC), a subsidiary of FirstEnergy Corporation, which also operates the corporation's two other nuclear power facilities: the two-unit Beaver Valley Nuclear Power Station in Shippingport, Pennsylvania and the single-unit Perry Nuclear Power Plant in Perry, Ohio.

Water Processing Capacity

Waste processing, an essential element of nuclear plant operations, has historically been handled in-house by plant personnel using vendor supplied equipment to supplement the original liquid radwaste (LRW) processing system.

Davis-Besse's LRW system consisted of a booster pump, chemical injection, 70-micron mechanical pre-filter, five demineralizer vessels designed for 50 gpm flow, and a 20-micron post polishing filter to remove any remaining micron level contaminants.

The booster pump supplied approximately 40 psi of pressure to drive the process water through this system. Though the LRW system was designed for 50 gpm, it was operated at 20 gpm because of the limitation of in-house plant filters that filtered the water a final time before it entered the monitor tanks for recirculation, sampling, analysis and release of the compliant water. During normal operations, the system flow would typically degrade from 20 gpm to 5 gpm as filters became fouled, at which time they would be changed by plant personnel. The filter replacement was required every two to three batches (typically 15,000 gallons each) of water processed. Unfortunately, supporting this effort put a demand on plant resources when they were least available, particularly during outages.

Because of the plant's low waste water generation rate, this modest processing rate was generally adequate to support plant operations, though during outages the LRW process system could be an operational bottleneck. In sum, while the capacity and capability of the LRW system was sub-optimal, it served the plant well for over 20 years. Challenges to the installed LRW system are detailed below.

Outages

During outages, when the largest volume of the most difficult-to-clean water is generated, Davis-Besse was hard pressed to process and release water fast enough to keep up with plant operations. Particularly challenging was the last foot of water during the refuel canal drain down. This water was drained to the Containment Normal Sump, then to the Miscellaneous Waste Drain Tank to then be processed by the LRW system.

Often, high activity water was continuously recirculated through the system in a generally unsuccessful attempt to reduce the activity concentrations to administrative release limits, which were substantially more conservative (lower) than regulatory release limits.

In some instances, the backlog of water to be processed delayed activities in the outage schedule.

Primary Spent Resin Sluice Water

When primary resins were sluiced to the Spent Resin Storage Tank (SRST), the excess water was decanted and sent off site for processing. This decanted water contained Co-60 at concentrations typically about E-2 uCi/ml (7.4E5 mBq). Though the LRW system typically reduced Co-60 concentration by a factor of 10 to 100, this was judged inadequate by Management, and the water was shipped off site for processing. The main culprit resisting LRW system decontamination was thought to be colloidal Co-60, a common water decontamination challenge.

LRW Effluent Quality

During the 20 years of LRW system operation at Davis-Besse, the quality of the system output released to the environment remained relatively stable. Unfortunately, expectations did not. What was acceptable effluent quality in 1997 was no longer adequate, as other plants progressively improved their LRW systems and reduced their already low release of trace contaminants. Based on peer-to-peer comparisons, the plant slipped in the industry ranking, as measured by discharges. By 2011, Davis-Besse had fallen to the third or fourth quartile for activity discharged.

Mandate to Improve

In 2014, Davis-Besse/First Energy determined that a revamp or upgrade of the plant's LRW system was in order. Plant personnel were tasked with identifying reputable vendors from which to solicit proposals for technologies and modifications that would meet plant processing needs within the space available. Where possible, to reduce waste generation, capital costs and installation time, it was desirable to use as many already-existing system components as possible.

Request for Proposals and Award

Ultimately, the plant requested commercial proposals from three industry vendors. Those vendors were asked to describe their technical and operating approach and state how, within time, space and budget constraints, the resulting LRW system would place Davis-Besse in the top quartile of PWR plants, reduce the amount of labor required to operate and maintain the system, and reduce waste volumes and the cradle-to-grave operating cost of LRW processing.

Based on price, technology and performance guarantee, the contract for the Davis-Besse LRW system upgrade was awarded in May of 2017 to AVANTech, Inc. of Columbia, South Carolina.

LRW System Modifications

The winning package combined existing equipment with a newly added feed booster pump to remedy chronically low system supply pressure, a Solids Collection Filter (SCF™) with shield, and a new bag prefilter (back-up to the SCF™) to replace the original (insufficient) unit. Four of existing demineralizer vessels were reused ahead of a new Radwaste Reverse Osmosis (RWRO™) System along with a 0.3-micron mechanical prefilter to protect the RWRO™ from particulate fouling. The RO permeate (clean water) would then be routed through the existing fifth demineralizer vessel for polishing with a mixed bed, followed by a final post filter to capture any resin fines or particulate. Importantly, plant piping was modified to by-pass the plant-installed filters which had been a flow capacity bottleneck.

A key aspect of AVANTech's Radwaste Reverse Osmosis (RWRO) system is that the reject from the RO unit goes back to the plant drain tank for reprocessing without having to be treated separately. This recycle system prevents a buildup of activity in the plant waste system, reduces mechanical complexity and waste volumes.

Additional Modification: Solids Collection Filter (SCF™)

A 10-micron (bag) pre-filter was chosen as the optimum micron prefilter to prevent fouling in the RWRO membrane system. However, there was concern that a 10-micron or smaller filter would reach maximum D/P in a short time and require frequent changes, given the heavy load of particulate and dirt inventory in the Davis-Besse's LRW system.

During plant walk-downs with AVANTech, the idea of adding a Sludge Collection Filter (SCF) to handle the large volumes of particulate in lieu of a bag filter was discussed. The SCF is an array of four canisters, each containing seven high capacity filter elements. The four canisters are plumbed in parallel inside a 120-cf steel liner. The hard plumbing allows the liners and canisters to be pressurized with no need for level control. Flow to each canister is self-levelling: as one canister accumulates a load of sludge, the process flow re-equalizes to provide greater flow to the others, ensuring a maximum sludge loading on all four canisters.

Originally designed for 800-gpm flow for torus cleanup at BWRs, the SCF is equally adept at collecting sludge from smaller waste streams such as the 25-gpm plant supply at Davis-Besse. To accommodate the lower flow rates, the diameter of the piping was reduced from 6" to 1.5" NPS.

A single SCF liner has the equivalent filtration capacity of approximately 1,760 bag filters, with a volume capacity of more than 30 cubic feet of sludge. The accumulated sludge in the SCF was expected to have high dose rates (but still be Class A), especially since SRST water would be processed through it.

To shield the 120-cf SCF liner, AVANTech also provided a 4-in. carbon steel annular shield with total weight of 50,000 lbs. that could be moved via forklift to the final installation area. The heavy shielding of the SCF ensures that exposure of transient personnel and staff working in the area is kept ALARA.

Performance, Pre- Modification

Pre-modification, Davis-Besse typically discharged 10 to 50 Millicuries annually of gamma emitting activity (past 7-year average: 19 Millicuries/yr), not including tritium, noble gases or beta emitters such as Fe-55, to Lake Erie. Additionally, to help minimize releases to the lake, Davis-Besse shipped SRST water containing +500 Millicuries of activity to an off-site processor annually.

In addition, the LRW system generated many filters which required manpower to process and dispose of, resulting in personnel exposure, shipments and disposal that all added to system operating costs. The inadequate LRW system generated excessive volumes of resin, particularly when attempting to achieve lower effluent activity goals or when attempting to capture hard-to-remove nuclides which required frequent change of resin and media.

Performance, Post Modification

Though at the time of this writing there have been just six months of operating experience with the upgraded LRW system, short-term results indicate that all the related Management goals will be met.

Davis-Besse's upgraded LRW system has processed four batches of SRST water which, prior to upgrade, would have had to be sent off site for processing. Additionally, the system has processed through an outage where activities are 10 times higher than normal operations.

In sum, to date, after processing 30 tanks, 4 SRST tanks and 1 outage, the system has only released 0.17 Millicuries of gamma emitting activity to the lake.

As expected, the pressure drop (D/P) on the SCF is still “0”. The RO prefilter downstream of the ion exchange vessels and upstream of the RWRO has been changed three times: these filter changes were necessitated by particulate from the vessels, which were not flushed prior to use with the RWRO. The dose rate of each filter was <1 mrem/hr, indicating that most of the collected material was non-radioactive in origin. As the inventory of particles attached to the sides of the demineralizer vessels and piping is exhausted, the change out of the prefilter is expected to drop to near zero.

The upgraded LRW system requires minimal operator input and interaction. Start-up consists of the operator verifying set points and starting both booster pump and RO unit via pushbutton. At set intervals, operators log system flow and pressure values. Upon completion of the run, the RWRO will auto-shutdown with loss of flow or by pushbutton securing of the booster pump and RO unit.

As anticipated, there has been no buildup of activity in the hold-up tanks or sumps from the reject that, instead of having to be reprocessed separately, is returned to the plant (a unique feature of the patented RWRO design). Currently, there is a buildup of activity in the SCF of +500 mrem/hr, with the outside of the SCF shielding reading less than 1 mrem/hr. Before system modification, this higher activity sludge was collected in LRW system filters, which had to be changed frequently. The SCF liner is expected to require change no more than once every 2-3+ years.

Issues

No solution, including this LRW system upgrade, is perfect or without secondary issues. There has been a modest increase in silica concentration in the plant radwaste system. The most likely source of the silica, which is rejected back to the plant by the RWRO, is lake water intrusions.

Silica can be removed by either of two methods. The first is to process a low activity batch of radwaste water with the RO bypassed. While this may marginally increase effluent activity, the increase is expected to be minimal as the process water is still routed through the SCF, 10-micron filter, full array of ion exchange vessels and polishing filter. The need for such action is indicated only if silica concentration exceeds 50-100 ppm in the radwaste system.

The alternative is use of anion resin to scavenge the silica from the process stream. This method was tested and successfully removed the silica, but is to be avoided when possible, as the additional waste volume is contrary to the goal of volume reduction. Through training, as plant operators become more aware of the impact of silica-containing Lake Erie water, steps can be taken to avoid or minimize lake water intrusions.

Summary

The modification/upgrade of the Davis-Besse LRW system with improved supply pressures, filtration capacity and installation of an RWRO is expected to move the plant to the top quartile of PWR plants while reducing the cost of labor required to operate and maintain the system. Reduced filter consumption and media waste volumes will help to lower cradle-to-grave operating costs for LRW processing. Activity has not built up in the plant’s radwaste system, though silica buildup will need to be monitored and addressed as levels dictate. In sum, the LRW upgrade at Davis-Besse is held to be a budgetary and operational success.