AVANTech's Liquid Radwaste (LRW) Processing System Upgrade at the Farley Nuclear Plant – 20328

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ABSTRACT

This paper looks at the Liquid Radioactive Waste (LRW) processing system configuration at Joseph M. Farley Nuclear Plant (Plant Farley). A combination of factors led the staff at Plant Farley to seek a better way to manage and process liquid waste. These factors were:

- Reduce effluent activity
- Reduce waste volume
- Improve cost efficiency

The LRW processing system changes made at Plant Farley are identified and discussed. The information and technologies 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.

INTRODUCTION

Plant Farley is a two-unit, Westinghouse three-loop PWR nuclear power plant. Located in Columbia, Alabama, Plant Farley is one of three nuclear power facilities in the Southern Company system (the others being Plant Vogtle and Plant Hatch, both in Georgia). Construction began in 1970, Unit 1 commercial operation began in December 1977, and Unit 2 commercial operation began in July 1981.

Water Processing Capacity

Waste processing, an essential element of nuclear plant operations, has historically been handled in-house by Plant Farley personnel using vendor-supplied equipment to supplement the original LRW processing system. Plant Farley's original vendor-supplied system had become unreliable and burdensome to operate, resulting in challenges to the processing schedule, especially during outages. Effluent activity performance was less than optimal, and waste volumes continued to increase.

A Need for Improvement

Based partially on the success of operating AVANTech equipment at Plant Farley's sister plant (Plant Vogtle Units 1 and 2), Plant Farley realized that a change was essential for the improvement of effluent releases and waste volume minimization.

In March 2007, AVANTech responded to Plant Farley's request for quote to discuss acquiring a patented AVANTech Radioactive Waste Reverse Osmosis (RWRO™)[1] System to augment their existing LRW processing capabilities. During those discussions, Plant Farley ultimately made the decision to replace the entire old system with a new AVANTech Liquid Radwaste System (LRS) combined with the Concentrate Treatment System (CTS™)[1].

[1] RWRO™ and CTS™ are trademarks of AVANTech, Inc.

DISCUSSION – SYSTEMS OVERVIEW

The LRS and the CTS™ provide a very unique approach that cleverly utilizes several technologies to their optimum benefits.

Liquid Radwaste System (LRS)

The **LRS** has a designed process rate of nominally 94.6 lpm (25 gpm). The LRS is a comprehensive approach to processing LRW in that it applies several proven technologies operating in harmony to produce an effluent of the lowest possible activity concentration. Three sub-systems, providing three unique purposes, are operated automatically with little operator action: the Tubular UltraFiltration (TUF™)[2] System, the RWRO™ System, and the Waste Processing System (WPS™)[2] – Ion Exchange System. The LRS is generally responsible for processing the plant's liquid wastewater to remove appreciably all of the radioactive isotopes.

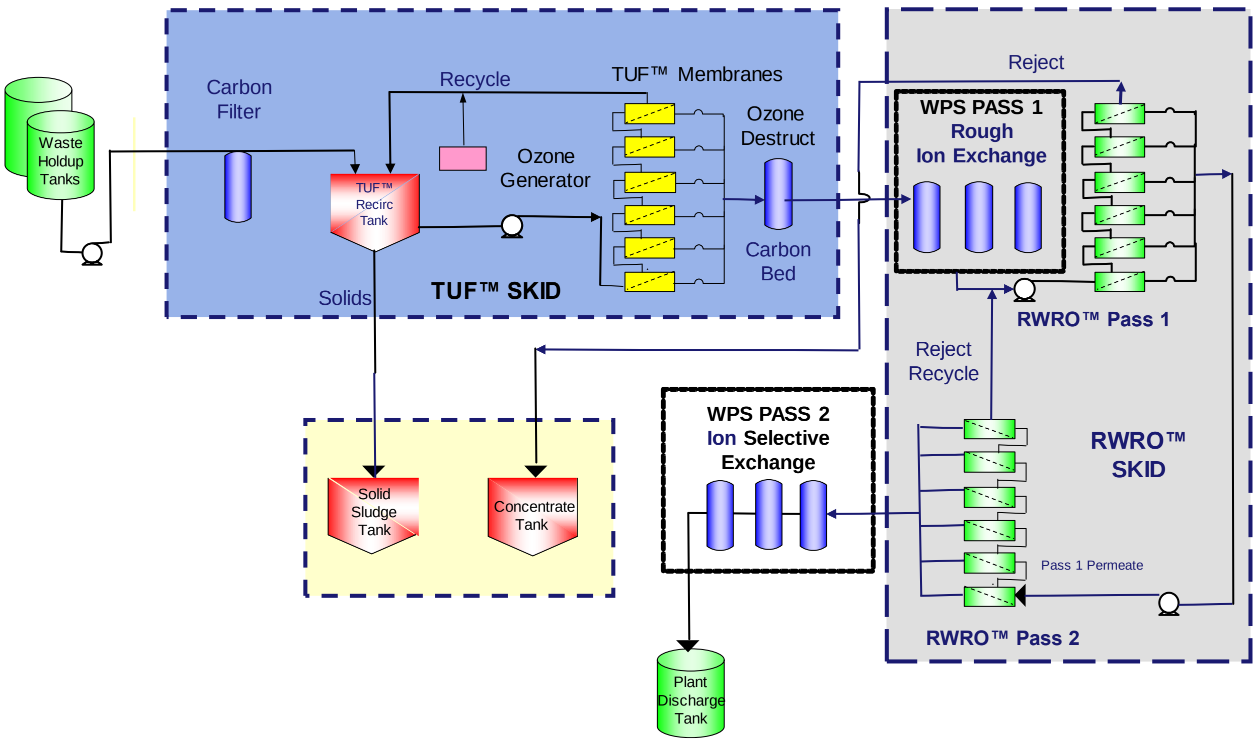

Fig. 1. LRS Process Flow Diagram

The LRS sub-systems perform the following general functions:

The **Tubular Ultra-Filtration (TUF™) System** removes particulate and organic materials from the incoming wastewater to allow for proper operation and efficiency of the RWRO™ System and WPS™. The TUF™ System utilizes cross-flow ultrafiltration technology with ten each ultrafilter membranes rated at 200,000 molecular weight cutoff. The resultant permeate filtrate has a turbidity of <0.1 Nephelometric Turbidity Unit (NTU). Virtually 100% of all particulate and organics are removed from the waste stream.

[2] TUF™ and WPS™ are trademarks of AVANTech, Inc.

The particulate and other contaminants are concentrated within the TUF™ System and are regularly pumped to the CTS™ for handling.

The patented **Radwaste Reverse Osmosis (RWRO™) System** removes the majority of the soluble (dissolved) radioactive isotopes and any remaining particulates from the wastewater. The reject is then concentrated and discharged to the CTS™. The RWRO™ System installed at Plant Farley employs a two-pass approach. The permeate from the first pass (nine membranes) is fed to the second pass (six membranes), maximizing the removal of the dissolved isotopes in the stream. One pass removes 96-97.5% of the isotopes; the addition of the second pass increases the efficiency of the RWRO™ to ~99% removal.

The isotopes are concentrated into a small stream, typically 1.9 to 7.6 lpm (0.5 to 2.0 gpm), which is delivered to the CTS™ from the first pass. Since the activity remaining in the stream delivered to the second pass is quite low, that concentrated stream is routed back to the feed of the first pass. This strategy minimizes the ultimate load on the CTS™ and maintains a nominal RWRO™ throughput of 94.6 lpm (25 gpm).

The **Waste Processing System (WPS™) – Ion Exchange System (Train #1 and #2)** performs ion exchange and polishing function, removing any remaining radioactive isotopes from the wastewater prior to plant discharge. AVANTech has taken a revolutionary approach to a conventional demineralizer system.

The WPS™ portion of the system consists of nine (9) ion exchange vessels:

- **WPS™ Train #1** contains five (5) vessels, each with a capacity of 0.85 m^3 (30 ft^3), located pre-RWRO™. The first vessel of Train #1 is loaded with carbon to provide gross filtration of the LRW stream just prior to the TUF™ System. The remaining four vessels are aligned just prior to the RWRO™ System. The next vessel is loaded with carbon as well, with the purpose of destroying/ capturing any remaining ozone/oxidizers from the TUF™ permeate (further protecting the RWRO™ membranes). The remaining two vessels are used as accumulators, loaded with media to remove the bulk of ionic species prior to the RWRO™ System and allowed to run to near 100% exhaustion. To further minimize overall waste generation, one of these accumulators can be reserved to receive media from WPS™ Train #2 to further utilize the ion exchange capabilities of that media prior to disposal. In typical systems, ion exchange medias are sluiced or removed from use and discarded as waste when they do not remove enough activity to meet effluent criteria. These beds may in fact be only 20-30% exhausted, but they are beyond their useful life for that process/stage.

- **WPS™ Train #2** contains four (4) vessels, each with a capacity of 0.85 m^3 (30 ft^3), located post-RWRO™. The four vessels of Train #2 act as a polisher for the RWRO™ permeate. The permeate is typically devoid of activity, and these vessels provide the opportunity to polish the permeate prior to entering the plant's release tanks. Train #2 vessels typically contain specialty/ion-specific medias (targeting the removal of cesium, antimony, etc.). Being placed downstream of both the TUF™ and the RWRO™ Systems, the water that is introduced into Train #2 is free of most activity, which makes the vessels very efficient polishers. When one of these polishing vessels have reduced efficiency due to the long useful life, it is then transferred to one of the accumulators in Train #1 to be repurposed and further utilize to the point of theoretical exhaustion, to minimize overall waste generation.

The **Ozone System** is installed to produce and inject ozone into the TUF™ System stream to destroy organic foulants that can collect on system membranes. The Ozone System is an essential technology that is +99% efficient at removing trace oils, greases, and other organic contaminants.

Concentrate Treatment System (CTS™)

The Concentrate Treatment System (CTS™) consists of the following subsystems:

The **Concentrate Drying System (CDS)** consists of the Concentrate Dryer and the Vapor Recovery Skid. The dryer is a horizontally mounted paddle wheel dryer that dries the concentrated particulate from the TUF™ System, spent media from the WPS™, and the reject from the RWRO™ System.

The dryer is operated under a vacuum created by the Vapor Recovery Skid at an evaporative rate of up to 94.6 lph (25 gph). The dryer is equipped with redundant level and temperature indications.

The vapor is condensed and returned to the Vapor Recovery Tank, which flows to the plant's Auxiliary Building sump. The dryer contents are typically completely dried and discharged into the waiting liner every 5,678.1 to 9,463.5 L (1,500 to 2,500 gal) batch. The dryer has a working capacity of 0.42 m^3 (15 ft^3) and an operating vacuum of 63.5 to 72.4 cm Hg (25 to 28.5 in. Hg).

The contents of the dryer are dried to ensure no free-standing liquid and are eventually discharged to an awaiting shielded liner.

The dryer level indication maintains a level in the dryer at or near 50%. When the level decreases to the low-level setpoint, the dryer is automatically refilled to the high-level setpoint from the Dryer Feed Tank (CDS-TK-1). The motive force is the vacuum in the dryer and the working atmospheric pressure in the Dryer Feed Tank.

The **Heat Transfer System (HTS)** consists of a small expansion tank, a centrifugal pump, and two banks of heaters. The fluid is heated and circulated at typically 400°F to provide the heat to the dryer to perform the evaporation.

The **Chilled Water System** provides the heat sink for the CDS. Chilled water is recirculated through the CDS condenser to condense vapor from the dryer as well as provide cooling water to the Vapor Recovery Skid vacuum pump.

The **Concentrate Holding System (CHS)** supports ongoing dryer operations. The concentrate/reject stream from the RWRO™ System is collected in the 11,356-L (3,000-gal) CHS Holding Tank. The system also has two centrifugal pumps (one pump in standby). During Concentrate Dryer operation, the tank is being recirculated. As the Dryer Feed Tank level decreases to its low-level setpoint based upon dryer demand, an air-operated valve opens to refill the Dryer Feed Tank to assure continued 24/7 operation of the dryer.

The **Solids Handling System (SHS)** collects any spent media from the WPS™ in the Spent Resin Storage Tank. The 3,785.4-L (1,000-gal) tank also collects the concentrated particulate from the TUF™ System. The Spent Resin Storage Tank has three possible outlets:

- First, the contents can be pumped as a slurry into the dryer, allowing the dryer to dry spent media.
- Second, the contents of the tank can be dewatered to the dryer. The dewatering connection is at a level in the tank of ~757 L (~200 gal).
- Lastly, the tank can be decanted at about 2,839 L (750 gal).

The SHS Pump (SHS-PP-1) is a single diaphragm sludge pump designed and well suited to pump media slurry or, in the case of dewatering/decanting, water from the Spent Resin Storage Tank to the dryer.

Areas of both the LRS and CTS™ portions of the system where increased dose rates can be expected are protected with concrete and carbon steel shielding panels as practical. Each system has a vast array of installed analytical instrumentation such as oxidation reduction potential (ORP), turbidity, conductivity, and pH. Some of the instruments are used as indication, and some are instrumental in the programmable logic controller (PLC) programming of the RWRO™ and TUF™ Systems operation.

INSTALLATION AND TESTING

Following some engineering, design and budget challenges (i.e.: post 9/11 upgrades, cybersecurity, HVAC System upgrades, and Flex), installation and (non-rad) startup of the LRS and CTS™ were accomplished in the spring/summer of 2015. Some essential activities that took place during this time were:

- Replacement of membranes in the TUF™ System
- Replacement of membranes in the RWRO™ System
- Oil change in all pumps
- Replacement of analytical instrumentation
- Site acceptance testing
- Water processed from the waste holdup tanks

All systems were tested successfully, including drying the contents of the dryer to dry solids with no free-standing water.

In the fall of 2015, some final design changes and budget constraints occurred at the plant resulting in the temporary suspension of the final start-up and turn over to operations. Consequently, the system was left in an as-is condition.

STARTUP / OPERATION

In the fall of 2018, all the final hurdles were crossed and AVANTech was brought back onsite to facilitate start-up and turn-over to plant operations.

Upon the initial inspection of the system, it was observed that several key components of the system had experienced some significant corrosion related failures. This prompted an in-depth inspection of the entire system. It was supposed that a volume of hydrochloric acid left in the system had slowly volatized in the humid atmosphere of the room and over time caused the ambient air to become acidic enough to affect several surface areas of the system. After the assessment, a detailed reclamation plan was established and implemented. The major areas of effort during the reclamation were:

- Replacement of the RWRO™ housings/membranes
- Replacement of the Dryer Feed Tank
- Replacement of all process hoses, as a precautionary step
- Replacement of the WPS™ Chemical Addition Skid (the suspected source of the acid)
- Replacement of the Vapor Recovery Tank
- Replacement of the stuffing boxes and packing on the Concentrate Dryer

Once the replacement/repairs had been performed and final inspection of the system completed, the LRS and CTS™ were placed into service in March 2019.

CONCLUSIONS

Plant Farley made the decision to employ the use of AVANTech's Liquid Radwaste System (LRS) combined with the Concentrate Treatment System (CTS™). This approach utilizes patented proven technologies that, when combined together, specifically targets the removal of both particulate and dissolved isotopes while minimizing waste generation and effectively producing superb effluent water quality.

<u>Effluent Water Quality</u> – Since the startup in March 2019, the LRS has processed over 4,731,765 L (1,250,000 gal) of water at an effluent quality of *less than Minimum Detectable Activity* (< MDA), tritium and noble gases not included.

<u>Waste Generation</u> – Only 1.42 m^3 (50 ft^3) of spent media has been transferred from the WPS™ to the SHS. This was the original loading of the gross filtration carbon bed. The total volume of waste dried and deposited is estimated at about 0.56 m^3 (20 ft^3) thus far into the liner originally installed with the system. It is expected that this liner will NOT require replacement until 2021.

<u>Operation</u> – The decision to add the full-time dedicated AVANTech Technician has ensured the successful performance of the LRS will continue with minimal interruptions, with minimal waste generation, while producing MDA effluent water.