MAKEUP WATER TREATMENT EXPERIENCE

Finetech, Inc. has been engaged in makeup water treatment for nuclear power and industrial applications since its founding in 1983. Finetech engineers have strong backgrounds in the research and development, design, startup, troubleshooting and evaluation of a wide variety of systems and materials used in the purification of water and other aqueous solutions. Applicable makeup water technologies in which Finetech engineers have direct experience and detailed knowledge include:

- Water Chemistry
- Ion Exchange
- Filtration
- Coagulation
- Adsorption
- Membranes Processes
- Chemical Cleaning & Sterilization
- Chemical Treatment

Technical experience encompasses all of the technologies utilized at electric power generating stations for water and waste purification. Some specific technologies which are pertinent to makeup water purification are:

Demineralization:	Bead and powdered ion exchange, regeneration techniques
Softening:	Ion exchange and physical/chemical (e.g., lime) processes, pre-treatment for reverse osmosis
Filtration:	Sand/gravel, multi-media, gravity, pressure, precoat, cartridge (pleated, fiber, membrane, hollow fiber, metal, media)
Membrane Separations:	Reverse osmosis (RO), ultrafiltration (UF), microfiltration, cross-flow filters, electro-deionization, antiscalant chemical programs; spiral, hollow fiber and tubular. Finetech staff experience with reverse osmosis dates back to the 1970s, with the design and testing of the original spiral membrane module configurations.
Absorption:	Granular and powdered activated carbon, and synthetic adsorbents

Deaeration:	Forced air, vacuum, steam, chemical (hydrazine and catalyzed oxygen removal systems)
Sterilization:	Ultraviolet light and ozone (also for organics destruction), chlorination, hydrogen peroxide
Evaporation:	Natural & forced circulation

Our staff's experience includes numerous applications of these and other processes at BWR, PWR, and fossil fueled electric generating stations as well as at industrial plants where water quality is of critical importance. Finetech's broad experience extends from conceptual designs through economic analyses and justifications to full implementation and troubleshooting at plant sites. Several of our Key Personnel are recognized within the nuclear power industry for their expertise in water chemistry, membrane processes, ion exchange, filtration and waste treatment systems. Finetech expertise in these areas is often applied on projects with the Electric Power Research Institute (EPRI), to which Finetech is a prime contractor.

Examples of Finetech makeup water systems design and optimization activities include:

- Conducted pilot plant evaluation programs of makeup unit operations
- Developed specifications for full-scale system designs
- Resin and membrane process selection for specific applications
- Developed criteria for membrane cleaning (frequency and chemicals used)
- Specified and assisted in implementation of antiscalants, dechlorination chemicals, acid and caustic to maximize performance
- Optimized pretreatment systems (media filters, clarifiers, granular activated carbon systems, cartridge filters) to maximize performance and extend membrane life
- Specified UV light systems to minimize biological activity and for TOC destruction
- Specification and optimum use of oxygen scavengers
- Improved operation of reverse osmosis systems in conjunction with makeup ion exchangers to maximize treated water quality
- Developed means of improving the reverse osmosis system control to extend membrane life
- Developed criteria for reverse osmosis and electro-deionization system operational and chemistry monitoring
- Assisted plants in troubleshooting makeup water quality issues.

Finetech has completed a number of projects that have resulted in design and operational improvements of makeup water systems. Our engineers have prepared design studies, design attribute reviews, system performance evaluations, safety evaluations, operating procedures and engineering packages. For these projects, Finetech's Senior Engineers have been personally involved in site visits and walkdowns, evaluations for assessment and improvement of existing systems, development of specifications and designs for new systems or upgrades, installation supervision, startup and troubleshooting. Examples of makeup water treatment projects include:

Plant A: Boiling Water Reactor Plant Makeup Water Treatment Systems

The original design of the demineralized water system at the Plant A station included ion exchange vessels with a cation bed, degasifier, anion bed, and final mixed bed before the demineralized water storage tanks. Water to the demineralizer vessels was pretreated via anthracite filters and a clarifier to remove suspended solids and activated carbon for de-chlorination and some reduction in total organic carbon (TOC). The demineralized water system was designed for a nominal flow rate of 150 gpm.

In 1987, the station was unable to consistently achieve makeup water quality limits for TOC and silica. The station had at that time obtained a small pilot scale RO unit using polyamide thin-film composite membranes and rated at 30 gpm, requested assistance to integrate the unit into the makeup water plant. Finetech was contracted by the utility to develop the design to integrate the pilot scale RO unit into the existing makeup water plant. This included the determination of the optimal location in the makeup water process, develop and specify the chemical pre-treatment process for anti-scaling control, develop and specify the in-place membrane chemical cleaning process, develop operating procedures, and support the environmental permit modification for RO installation, since the concentrate stream from the RO process was to be directed to the discharge canal and trace amount of acid from the anti-scalant addition as well as membrane cleaning chemicals would potentially end up in the discharge canal. Integration of the pilot unit posed design challenges since the demineralizer beds were designed for a nominal process flow of 150 gpm, while the permeate flow of the pilot RO unit ranged from 5 to 15 gpm. To minimize chemistry excursions when making up water to the demineralized water storage tanks as a result of flow channeling through the ion exchange beds, the design included a continuous recycle of RO permeate water back to the front end of the system and special flush/purge instructions before water addition to the demineralized water storage tank.

Finetech was tasked by the station to prepare the report documenting performance results of the pilot RO system in the makeup plant, preparing a report recommending going forward options for the design of a full scale RO system for the makeup water plant, and preparing the equipment specification for the full scale RO system. The pilot RO unit operated successfully in the makeup water plant at Plant A from 1988 to 1996. Plant A has historically used a low volume of makeup water. The full scale RO unit was

finally installed in 1996, when the station had to completely empty the torus to perform ECCS suction strainer modifications.

The success of the pilot scale RO unit in conjunction with the low makeup water usage rate at FitzPatrick, led the station to discontinue ion exchange resin chemical regenerations. The acid and caustic tanks were emptied in the early 1990s and the tanks eventually permanently retired.

Plant B: Pressurized Water Reactor Combined Site Makeup Water Treatment Plant Design

The Plant B In-House Water Factory (IHWF), which was supplied by city water, consisted of a flocculation system, raw water booster pumps, carbon filters, cation exchangers, vacuum degasifier, anion exchangers, mixed bed demineralizers and an ultrafiltration system. Due to the age of the system, original components had become unavailable through obsolescence, therefore, replacement of failed components became expensive and time consuming engineering modifications. Additionally, tightening of water quality requirements necessitated upgrading the makeup water system.

Finetech was tasked to perform a study to evaluate options for provision of demineralized water to meet the capacity demand and quality requirements of Plant B. Three base options considered were:

1. Refurbish the Plant B IHWF
2. Install a contractor water treatment system (CWTS) to meet IHWF makeup water requirements for Plant B
3. Partner with Plant C in a joint Plant B/Plant C CWTS

Sub-options were considered for each of the base options.

The evaluation included walkdowns, interviews with operations, maintenance and chemistry personnel, reviews of operating history, assessments of system and component condition, and reviews of work requests and problem identification inquiries. Financial evaluations were performed including equipment costs, operating costs and costs associated with a CWTS.

The recommendation for Plant B was for a full CWTS. As part of the report, Finetech prepared a specification for a permanent CWTS, a preliminary engineering (conceptual design) package for permanent tie-ins for the CWTS and a feasibility study for power supply to the new CWTS. Engineering support continued through the installation and startup in the late 1990s of a CWTS, to supply both Plant B and Plant C.

Plant D: Boiling Water Reactor Plant New Makeup Water Treatment System Specification, Design and Implementation: This project began with a procurement specification development for a new makeup water treatment system. Proposals were

solicited and received for systems from several different providers of leased and permanent equipment systems. The processes evaluated included filtration, adsorption, degasification, softening, chemical addition (acid or synthetic antiscalant), reverse osmosis (single pass and dual pass), membrane cleaning subsystems, electrodeionization, ultraviolet light system for organic destruction, final polishing ion exchange and ultrafiltration. The evaluation was completed in October, 1994, and the system was installed in 1995 and successfully commissioned in 1996.

Plant E: Pressurized Water Reactor Makeup Water System Conceptual Designs and Upgrades:

Plant E is a dual unit PWR. The station does not recover steam generator blowdown on the secondary side, and as a result, a high continuous makeup water rate is needed to support operation of both units, on the order of 600 gpm total flow. The station's original design of the makeup water plant consisted of three redundant ion exchange trains with chemical regeneration. The makeup water process was modified to include to full flow redundant RO trains, upstream of the ion exchange beds. Prior to installation of RO, chemical regenerations were performed on a daily basis; with RO, regenerations are performed about once every 10 days.

Finetech was involved with two makeup water project upgrades for Plant E. The first was to design, procure, fabricate and deliver an upgrade to the RO acid injection system, as the acid chemical injection system for anti-scaling control was failing due to accelerated corrosion (2000-2001 project). Finetech engineered a design upgrade that included the installation of injection quills and alternate piping/tubing for improved corrosion resistance. The injection quill design was installed by the station with on-site support by Finetech.

Another makeup water project was to perform a conceptual design of an upgrade to the main acid and caustic piping systems used for resin regeneration (2005-2006 project). This project was to optimize the acid and caustic system designs, including piping and controls, to eliminate excessive chemical leakage. The station had experienced several acid and caustic chemical leaks over the years at process piping connections that had created personnel hazards as well as failed process equipment, and failed structural components (concrete, supports).

Pharmaceutical Makeup Water Systems Designs, Upgrades and Monitoring:

Finetech was tasked to perform a study to determine and describe feasible means of upgrading Deionized Water (DIW) System hardware and operations to provide water at specified quality for makeup to boilers and factory points of use in quantities sufficient to meet projected demands. The DIW system effluent consistently met the quality specifications for water to be used for makeup to boilers. However, there was a chronic deficiency in exceeding the CFU/ml (colony forming units/ml) specifications for factory water. Therefore, the upgrades to hardware and system operation were for bacteriological controls as well as water quality.

Some recommendations from the study included:

1. Changes to sodium sulfite usage
2. Installation of HEPA filters on vents
3. Nitrogen blanketing storage tanks
4. Recycle of a portion of UV effluent to the storage tank
5. Anion resin replacement
6. Installation of reverse osmosis units
7. Upgrade instrumentation

Costs for materials/equipment and the change in projected operating costs were estimated.

The DIW system was upgraded in 1999.

In 2002, Finetech was tasked to perform an evaluation of the design and operation of the water plant that supplies deionized water to the manufacturing division and to the research laboratories at the facility. The study was undertaken in response to several problem areas identified by site facilities personnel. These included:

- Loss of filter media from the Multi-media filters
- Media found in downstream processes
- Reverse Osmosis (RO) membrane life shorter than expected
- Continuous Deionization (CDI) effluent water resistivity not as high as expected
- Water usage higher than desired

The source of water for the water plant is drinking water from a local water utility. After entering the building, the water undergoes pretreatment (multi-media filters, softeners, heat exchanger, ultraviolet sterilizers, cartridge filters), followed by membrane processing (reverse osmosis units), polishing (continuous deionization units) and then is stored in two storage tanks. One tank supplies the manufacturing division and the other supplies the research laboratories.

The approach taken was to begin at the front end of the system, starting with the multi-media filters with which there were known problems, and work downstream to assess each system's performance to its capability.

Recommendations along with benefits associated with the recommendations and estimated costs were provided for the multi-media filters, softeners, RO pre-filters and RO units. From a system perspective, recommendations, associated benefits and estimated costs were provided for design documentation, operating instructions, a monitoring program and a periodic system "Snapshot", a sampling and analysis program that takes a "snapshot" of the chemistry of the entire system. Snapshot

sampling was performed in 2003 and 2004. Finetech coordinated the sampling program and evaluated the analysis results.

Finetech was tasked to perform a study to evaluate the feasibility of routing the Reclaim Reverse Osmosis (RO) Reject water from one water plant to the Raw Water Tank of a second water plant. It was initially estimated that this could reduce city water use by approximately 2.42 million gallons per month. The work included sampling and analysis of the Reclaim RO Reject water, computer modeling to project the impact on the second water plant operation, an engineering evaluation of the other technical impacts and a cost-benefit analysis. The second water plant provides demineralized water for boiler water use and thus is not a validated system. Finetech also performed the detailed engineering for the design changes leading to system installation and startup in the 2004 timeframe. The system met the original goals of cost savings from lower city water usage and reduced liquid discharges.