

Delivering the Nuclear Promise

Top Innovative Practice



December 16, 2022

DNP-TIP-2022-05

Nanofiber Technology for Aqueous System Filtration

2022 Top Innovative Practice Winner

Summary

To support its Source Term Reduction Program, Beaver Valley Power Station (BVPS) engaged Framatome's Nuclear Parts Center (NPC) to design a drop-in replacement filter cartridge for the plant's reactor coolant system (RCS) filtration applications. The objectives for the design were to remove RCS contaminants (e.g., particulates and colloids), reduce source term and radiation levels, and extend equipment service life with fewer filter change-outs and a lower total cost of ownership. Framatome's filter cartridge design team leveraged its exclusive relationship with Nano Technologies Inc. (NTI) to incorporate its nano-fiber technology as a cornerstone of the cartridge's design. NTI's nano-fiber media uses electro-adsorption to attract contaminants instead of conventional mechanical particle size exclusion. The electro-adsorptive properties of the nano-fibers make the filter highly efficient in the removal of waterborne contaminants in the sub-0.1 μm range, while its open pore structure results in higher permeability, lower pressure losses, and higher holding capacities. To house the nano-fiber media, Framatome engineered a one-piece drop-in replacement cartridge with an integrated upper-end seal assembly, thereby eliminating the more complex and costly two-piece design and traditional O-ring seal. Using the Framatome and NTI filter solution, BVPS is achieving its Source Term Reduction Program objectives with fewer Cat-IDs, lower material unit costs, improved filter installation/removal efficiencies, and fewer filter change-outs for an overall lower total cost of ownership.

Innovation

Framatome's filter cartridge design leveraged its exclusive relationship with Nano Technologies, Inc. (NTI) to incorporate its nano-fiber technology within the filter media. NTI's nano-fiber media uses electro-adsorption to attract contaminants instead of conventional mechanical particle size exclusion. Due to unique properties of the nanofiber, when introduced to water, the fibers take on a positive surface charge greater than 50mV and attract the electrically charged colloids that are otherwise unable to be removed.

Safety

Conventional filters mechanically intercept and retain contaminants via particle size exclusion, and the fiber-mesh or pore size is the limiting condition related to efficiency. According to EPRI report NP-522, 30% of particles are not filtered due to this physical limitation. This 30% is composed of solubles, particles, and colloids that are commonly known as CRUD. Reduction and removal of these colloids eliminates the risk of them ultimately causing radioactive embrittlement, compromised thermal efficiency of rods, increased corrosion, potential fuel failure, and radiation migration. The electro-adsorptive properties of the nano-fibers make the filter highly efficient in the removal of these waterborne contaminants in the sub-0.1 μm range;

while its open pore structure results in higher permeability, lower pressure losses, and higher holding capacities. The Framatome and NTI filter solution is helping BVPS achieve its Source Term Reduction Program objectives by retaining greater than seven times the dose of conventional 1 micron media.

Furthermore, the Framatome-engineered cartridge design incorporated several key features to support nuclear and industrial safety. The silicone encapsulated upper and lower ends of the Framatome housing design eliminated the all-metal housing and ends of the existing OEM design which are susceptible to damage from impact during installation. Framatome's housing also removed the existing split O-ring seal that could result in foreign material entering the system. Both features eliminate 100 manhours in containment for filter replacement and foreign media retrieval. The open top design allows for water drainage prior to removal that was not possible with the previous closed top cap.

Cost Savings

The Framatome/NTI filter solution resulted in reduction in material unit costs by 15% per year, improved filter installation/removal efficiencies, and fewer filter change-outs for an overall reduction of \$25,000 per application per year. Depending on remaining life of the plant and number of applications, the site could ultimately realize over \$1 million in savings.

To house the nano-fiber media, Framatome engineered a one-piece drop-in replacement cartridge with an integrated upper-end seal assembly, thereby eliminating the more complex and costly two-piece design and traditional O-ring seal. Framatome's proprietary integral seal also eliminated the need to apply lubrication during install which again saves dose, costs, and maintenance hours at approximately \$5,000 per application.

Productivity/Efficiency

The Framatome/NTI filter solution is helping BVPS achieve improved filter installation/removal efficiencies, and fewer filter change-outs at a rate of 100 manhours per application per year. In addition, efficiencies are achieved through reduced filter cartridge lead times. Again, depending on the remaining life of the site, this would be man-months of productivity savings and opportunity cost savings.

Transferability

Framatome/NTI's nanofiber media can be housed in any aqueous filter cartridge application and is used exclusively in Framatome's drop-in replacement filter cartridge designs. Testing data and design enhancements generated in support of the BVPS design can be leveraged by other aqueous applications and sites within and outside of the nuclear industry.

Many variations within the OEM designs for primary system applications result in a lack of versatility in shared application. Framatome top and bottom designs can consolidate OEM designs to fewer variations to allow for more flexibility of use and reduction in spares needed to maintain ability to support operations.

Team Members

- Jeffrey Fontaine, Radiation Protection Supervisor (Energy Harbor)
- Ryan Kurylo, Radiation Protection (Energy Harbor)
- Taylor Smith, Product Manager (Energy Harbor)
- Joel Farrar, Product Technical Specialist (Energy Harbor)

- Scott York, Radiation Protection and Chemistry Services Manager (Energy Harbor)

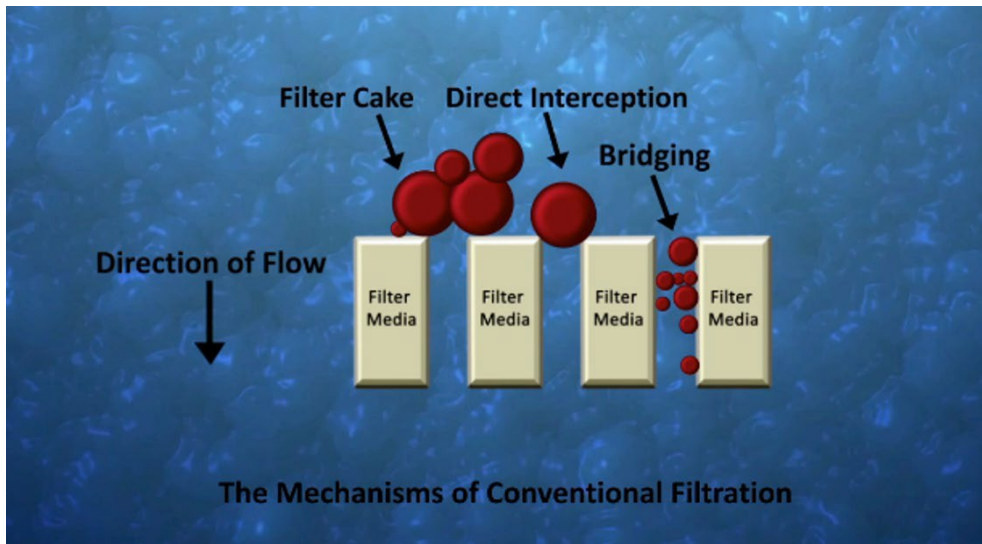


Figure 1 - Conventional Mechanical Filtration

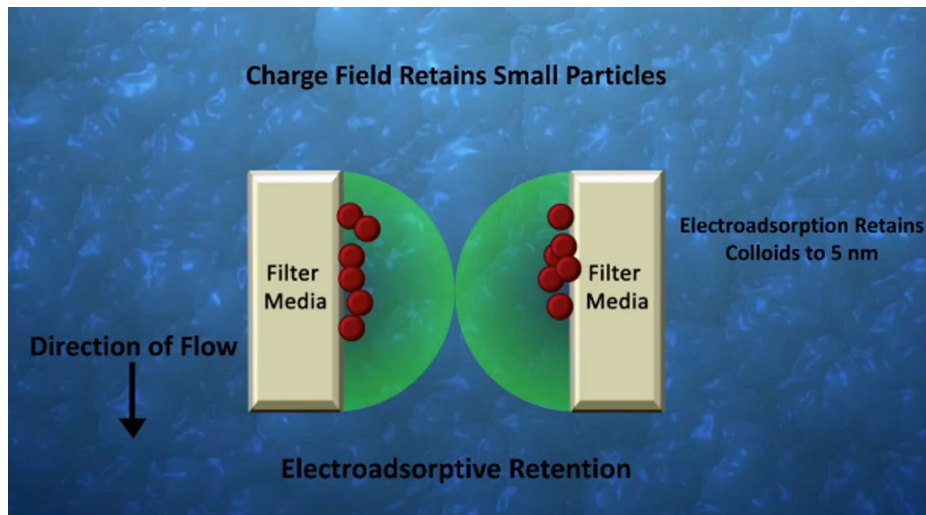


Figure 2 – Electroadsorption Retention

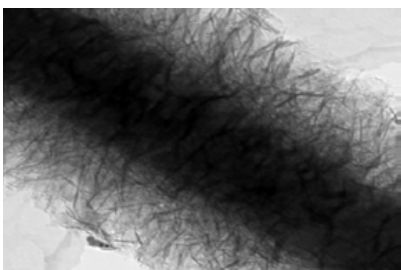


Figure 3 - NanoFiber