300 GPM Solids Removal System
A True Replacement for Back Flushable Powdered Filter Systems - 13607

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ABSTRACT

The Energy*Solutions* Solids Removal System (SRS) utilizes stainless steel cross-flow ultra-filtration (XUF) technology which allows it to reliably remove suspended solids greater than one (1) micron from liquid radwaste streams. The SRS is designed as a pre-treatment step for solids separation prior to processing through other technologies such as Ion Exchange Resin (IER) and/or Reverse Osmosis (RO), etc. Utilizing this pre-treatment approach ensures successful production of reactor grade water while 1) decreasing the amount of radioactive water being discharged to the environment; and 2) decreasing the amount of radioactive waste that must ultimately be disposed of due to the elimination of spent powdered filter medias.

INTRODUCTION

Although the basic scientific principles behind organic polymeric membrane technology were developed in the 1950s, it was not until fairly recently that inorganic cross-flow membrane technology began to be recognized as an efficient, economical, and reliable solids separation process. In the last 10 to 15 years, the technology has proven to be reliable and has gained acceptance as a viable solids separation option for many waste streams.

TECHNOLOGY DESCRIPTION

Conventional dead-end filtration methods operate with the waste feed flow in the same direction as the permeate flow (i.e., into the filtration media). An alternative method is to recirculate the waste feed and thereby maintain a high velocity of flow parallel, or cross-flow, to the filter media surface. This helps minimize particle build-up on the filter (for a comparison of conventional "dead-end" filtration and "cross-flow" filtration reference **Figure 1**).

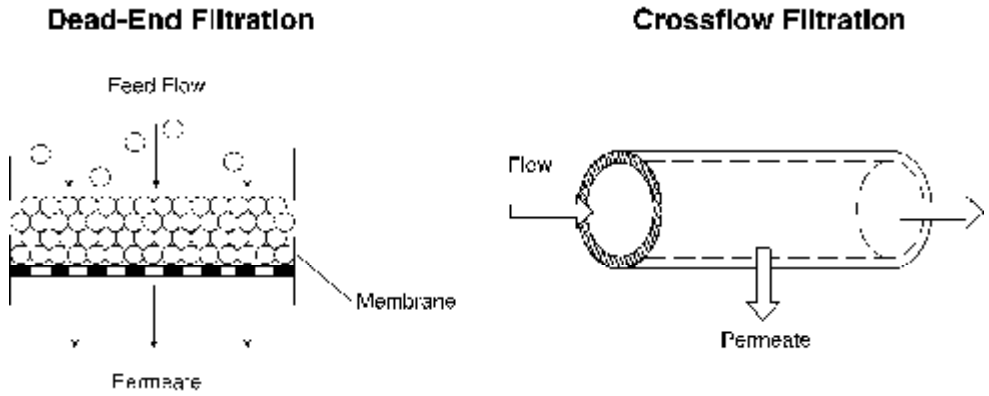

Figure 1 - Comparison of conventional "dead-end" filtration and cross-flow filtration[2].

The disadvantages of using conventional dead-end filtration methods include:

- filtrate flow (flux) decreases rapidly as particle layers accumulate on the filter,
- continuous particle layer build-up results in low overall flow rates,
- frequent cleaning or change out of filters is required,
- filter aids are often needed which can significantly increase waste volume and disposal costs.

While cross-flow filtration does not completely eliminate the particle boundary layer, it does lead to higher flow rates as shown in **Figure 2**.

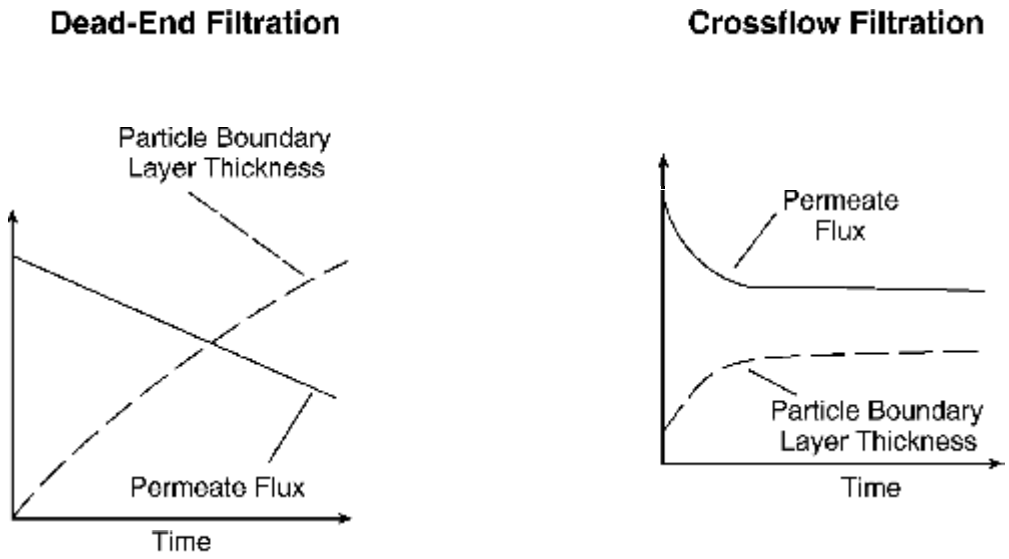

Figure 2 - Comparison of flux rates and particle boundary layer thickness[2].

The XUF technology maximizes high flow, high shear, and high flux which equates to reliable high processing rates in heavy suspended solids environments and affords the possibility of near steady state operation.

The XUF technology offers an ideal solution for filtration challenges having the following characteristics.

- High shear, high flow, high flux = minimal fouling in high Total Suspended Solids (TSS) streams
- Can operate under high pressures and transmembrane velocities = high throughput
- Flux readily restored by backwashing and/or chemical cleaning = minimal downtime

CLIENT'S CHALLENGE

Boiling Water Reactors (BWRs) typically incorporate large back flushable powdered filter systems that are utilized for solids separation removing contaminates from their liquid radwaste streams prior to being processed by large demineralizers. The presents of very fine particulate and iron oxide in the waste feed are proving increasingly difficult to treat reliably.

One BWR requested Energy*Solutions* to identify a technology that would be a true replacement to their existing in-plant powdered media filter system. Their goal centered on the following: 1) Remove iron oxide and other suspended solids from their liquid radwaste; 2) Continue to use their in-plant demineralizers; and 3) Sustained ≥150 GPM Flow Rates (stressed conditions).

Approach

Energy*Solutions*' approach to the client's request was as follows:

- Determine the client's liquid radwaste processing goals
- Spend time at client's site and learn their liquid radwaste systems first hand
- Identify waste streams (normal and off-normal conditions)
- Retrieve samples and have them analyzed by a third party
- Compare sample data with historical data to identify any anomalies
- Evaluate previous technology (what's worked / not worked)
- Select technology
- Conduct "proof of process" testing using the selected technology with actual waste

Client Goals

After meeting with the client's stake holders the following goals were identified:

- Only remove iron oxide / suspended solids >1 micron
- Pre-treatment for existing in-plant demineralizers (or future Reverse Osmosis)
- Sustained ≥150 GPM Flow Rates (in stressed conditions)
- Reduce Liquid Radwaste Discharges to the environment and increase Water Recycling
- Reduce / Eliminate Powdered Media (purchase and disposal)
- Reduce Personnel Exposures (ALARA)
- Increase System Reliability
- Increase System Life (to match plant license renewals)
- Reduce / Eliminate the reprocessing of Suspended Solids

Waste Stream Investigation

Energy*Solutions*' spent approximately thirty days at the client's site learning and investigating their active liquid radwaste streams. During this time interviews with chemistry, operations, radiation protection, ALARA, maintenance and engineering were completed with the goal to learn each stake holder's challenges and determine waste stream conditions for normal and off-normal conditions. In addition, waste samples of each waste stream were obtained and sent off for analysis. The results were then compared with historical data to identify any anomalies (reference **Table 1** for a summary by waste stream). Once all the data was reviewed and understood Energy*Solutions* identified and confirmed the technology choice - the Solids Remove System utilizing the XUF technology.

Table 1 - Waste Stream Summary

12 to 14 Million Gallons Annually	Volume %	Waste Stream (by Tank Name)
Low Total Suspended Solids (TSS)	~65%	EDCT-A, EDCT-B, WST-B
High Total Suspended Solids (TSS)	~35%	FDCT, WST-A, Resin Cleaning System

Proof of Process Testing

To confirm that the XUF technology was capable of meeting the client's goals a demonstration was conducted using Energy*Solutions*' XUF pilot system. For three months the pilot XUF processed actual liquid radwaste processing ~5,000 gallons (~18,927 liters). All Suspended Solids that were removed by the XUF were returned back to the SRS feed tank for reprocessing (continually creating a more challenging waste stream). **Figure 3** shows the waste streams processed and identified by waste tank name.

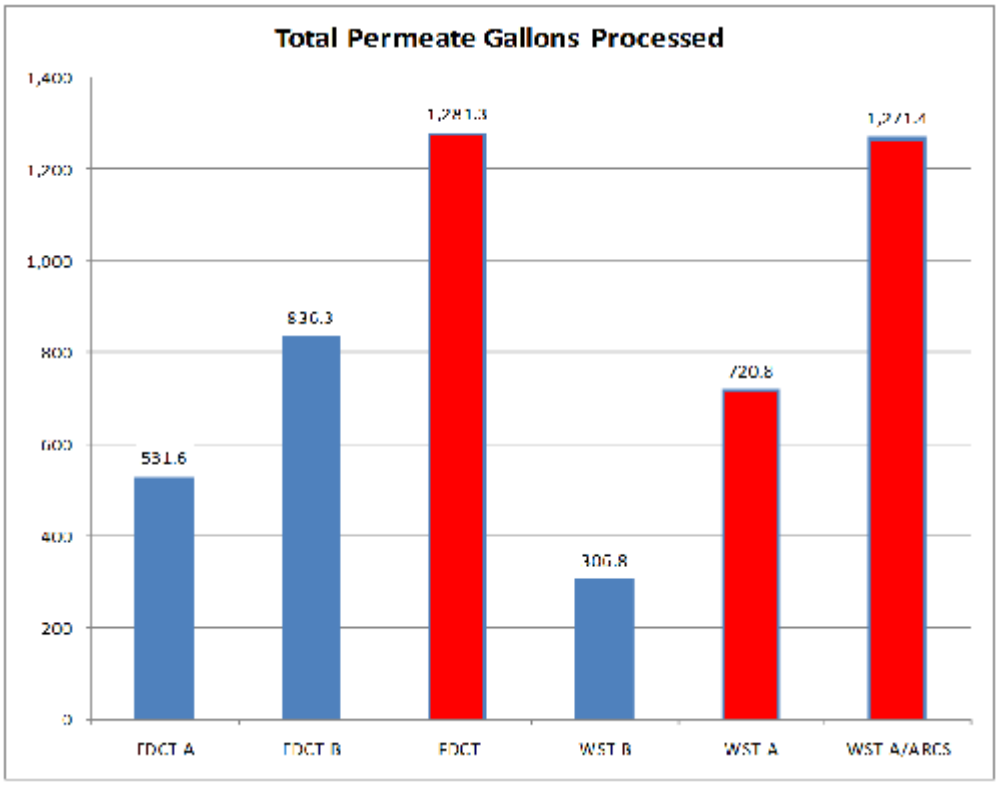

Figure 3 - Total Gallons Processed by Waste Tank

Valuable information was obtained during this testing of actual liquid radwaste which was utilized in the design of the full scale Solid Removal System.

PERFORMANCE

The Energy*Solutions* XUF technology has proven to be excellent at removing suspended solids from radioactive liquid radwaste streams. This was proven not only during the onsite proof of processing testing but post fabrication as well.

Table 2 shows the solids removal performance and **Table 3** shows the radiological removal performance when processing actual liquid radwaste.

After the full scale 300 GPM (1,136 LPM) SRS was constructed an aggressive acceptance test was performed. For three months over 1.75 million gallons (6,624 M^3) of various surrogate waste streams were processed to prove its capabilities prior to delivery to the client.

Table 2 - Solids Removal Performance

Permeate Sample	B&W Iron (ppb)	X Ray Fluoroscopy (ppb)	Notes
10/27/2009 @ 1032	<10	2	30 min after backwash
10/27/2009 @ 1059	<10	2	1 hour after backwash
10/27/2009 @ 1130	<10	0	1.5 hours after backwash
10/27/2009 @ 1159	10	3	2 hours after backwash
10/27/2009 @ 1259	<10	0	3 hours after backwash
10/27/2009 @ 1310	150-250	89	2 min post backwash
10/28/2009 @ 1208	25-50	21	10 min after backwash
10/28/2009 @ 1218	10-25	2	20 min after backwash
10/28/2009 @ 1228	10	0	30 min after backwash
10/28/2009 @ 1409	150-250	53	3 min after backwash

Table 3 - Radiological Removal Performance

Nuclide	XUF Feed (µCi/ml)	XUF Permeate (µCi/ml)	(A / B) Reduction Factor	(A to B) % Change
AG-110M	1.65E-06	ND	Removed	-100.0%
BA-140	1.20E-05	1.59E-06	7.55	-86.8%
CE-141	7.60E-06	ND	Removed	-100.0%
CO-58	1.03E-05	1.19E-07	86.55	-98.8%
CO-60	2.06E-04	5.83E-07	353.34	-99.7%
CR-51	6.59E-05	ND	Removed	-100.0%
CS-137	4.46E-07	9.04E-08	4.93	-79.7%
FE-59	8.86E-06	ND	Removed	-100.0%
I-131	1.29E-06	7.66E-07	1.68	-40.6%
I-133	2.72E-06	2.47E-06	1.10	-9.2%
I-135	ND	9.29E-07	#VALUE!	#VALUE!
LA-140	1.02E-05	8.75E-08	116.57	-99.1%
MN-54	1.14E-04	3.35E-07	340.30	-99.7%
MO-99	ND	2.13E-07	#VALUE!	#VALUE!
NA-24	1.79E-06	1.51E-06	1.19	-15.6%
NB-95	4.59E-07	ND	Removed	-100.0%
SR-91	ND	1.85E-07	#VALUE!	#VALUE!
SR-92	2.61E-07	ND	Removed	-100.0%
TC-99M	8.60E-07	2.35E-07	3.66	-72.7%
XE-133	ND	3.37E-07	#VALUE!	#VALUE!
XE-135	4.46E-07	4.15E-07	1.07	-7.0%
ZN-65	6.92E-05	1.33E-06	52.03	-98.1%
ZN-69M	2.70E-07	ND	Removed	-100.0%

Measured Total	**5.15E-04**	**1.12E-05**	**45.98**	**-97.8%**
Note: Nuclides I-135, MO-99, SR-91, and XE-133 were reported as none detectable (ND) in the XUF Feed but were identified present in the XUF Permeate. All isotopic data was utilized as it was reported.				

Figure 4 - Visual (Before and After)

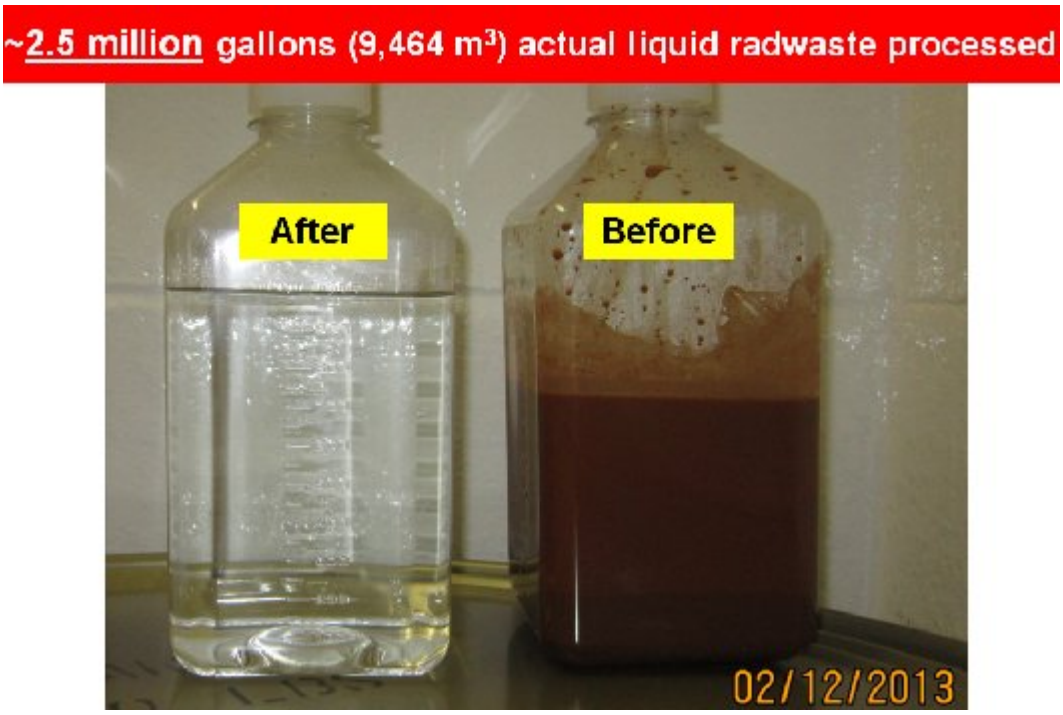

Figure 5 - Visual (Before and After)

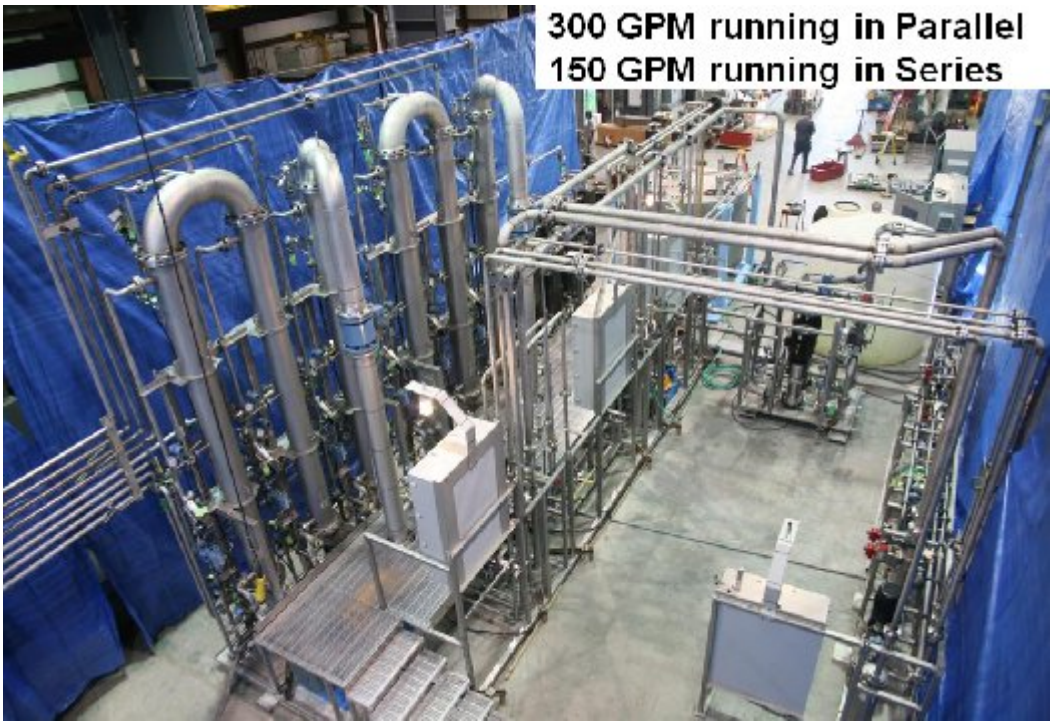

Figure 6 - Picture of the full size system after construction

CONCLUSION

The Solids Removal System has been in full operation since December-2012 and has successfully processed over **2.5 million gallons** (**9,464 M^3**) of liquid radwaste to date.

The Energy*Solutions* XUF technology has proven to be excellent at removing suspended solids from liquid radwaste streams. Low operating costs, durable membrane life, and the ability to remove organic and iron contaminants make the XUF an attractive technology that is effective in eliminating or substantially reducing many contaminants.

For additional system pictures and graphs please refer to the associated EnergySolutions Power Point Presentation with the same name as this paper.

REFERENCES

1. Energy*Solutions* Power Point Presentation with the same name as this paper.
2. Innovative Technology Summary Report, DOE/EM-0370, Crossflow Filtration, Tanks Focus Area, Office of Science and Technology (OST) Reference # 350