ADVANCED WATER PROCESSING SYSTEM (AWPS), INCLUDING ADVANCED FILTRATION SYSTEM (AFS) AND ADVANCED ION SELECTIVE SYSTEM (AISS) FOR IMPROVED UTILITY (PWR/BWR) WATER PROCESSING PERFORMANCE

Mark S. Denton, Ph.D., ATG, Inc.
Jene N. Vance, V&A, Inc.

ABSTRACT

The Advanced Water Processing System (AWPS) has the potential for wide spread success on a worldwide scale in both PWRs and BWRs. The AWPS incorporates the advanced features (patent pending) of Advanced Filtration and Advanced Ion Selective technologies (patented). Typical problems encountered in current filtration systems include: (1) poor effluent quality, (2) short run lengths on filters, (3) frequent filter change-outs/backwashes, (4) large waste volumes, and (5) failed filter cartridges. The Advanced Filtration System (AFS) features reduced waste production per million gallons of water processed, cleaner water for recycle or release to the environment, filter element volume 100 times less than that of competitive filters, and a far lower capital cost compared to systems with similar performance.

The AWPS should be of interest to plants that are upgrading, or to new plants to lower both their capital and operating costs, as well as total curie discharge levels. In addition, the AWPS will function in non-nuclear, as well as nuclear, applications of water purification, especially where precoat filtration/ion exchange or reverse osmosis (RO) is being applied to process water with high concentrations of colloidal contaminants.

Pilot testing has been successfully completed in the U.S. at the Byron (PWR), LaSalle (BWR), and Dresden (BWR) nuclear plants for Commonwealth Edison, and the Bruce Stations in Canada for Ontario Hydro. The data from these bench- and pilot-scale demonstrations will be presented herein. Full-scale designs or systems have been shipped to these locations.

In all cases, the testing demonstrated: (1) longer run lengths (300,000 gallons between backwashes—a 100 fold improvement), (2) recoverability of cartridge filters after backwash (cartridge lives of approximately 6 months to a year—a 5 to 10 fold improvement in filter life), (3) large removal efficiencies for colloidal particles (reduced discharge curies), and (4) reduced waste volumes (particularly resin volumes). Evaporation and drying has been combined to create a greatly improved process, especially when the customer can send sludges and/or resins to the ATG Catalytics facility in Oak Ridge, Tennessee. Filtration and selective media systems have been provided on a service basis (by month or gallon) or sold outright to the utility.

Typical problems encountered in current demineralization/media systems include build-up, recycle, or bleed of cesium (Cs), cobalt (Co), boron (B), and iron (Fe) in BWRs and Cs, Co, antimony (Sb), and B in PWRs. The Advanced Ion Selective System (AISS) features specific ion removals rather than brute force techniques such as total demineralization or reverse osmosis, thus offering smaller equipment skids, subsequent reduced capital and operating cost, greatly reduced waste volumes, lower curie discharge, and eliminates the chance of accidental releases/spiking during plant upsets. Such media can also be added solely to existing, available vessels or to top off existing media.

ADVANCED FILTRATION SYSTEM (AFS)

Background

Liquid waste processing is best understood by discussing the processing at the two types of LWR reactors: BWRs and PWRs. With a couple of exceptions, most BWRs use in-plant filtration and ion exchange equipment. BWRs typically recycle equipment drain water after treatment by filtration and ion exchange. Because of the high quality of equipment drains, these treatment methods are relatively effective in treating this waste stream in terms of meeting recycle water quality and solid waste volume generation rates from the treatment processes. Typically BWR floor drain water is also treated by in-plant filtration and ion exchange. In some plants, the floor drain water is discharged after treatment and in other plants the water is recycled following treatment. The limiting water quality parameter that usually controls the decision to recycle or discharge is the concentration of total organic carbon (TOC) in the treated water. It is generally difficult to remove the TOC down to levels suitable for recycle using the ion exchange processes in plants. The ATG system proposed (e.g., LaSalle) will achieve TOC reductions equivalent to any commercial system (e.g., UF or RO) with significantly lower costs, including capital, operating, and waste. The floor drain treatment processes generate large volumes of solid waste, both from the filtration and the ion exchange processes. The BWR segment has the largest volume of water to process. Volumes range from 5 M gallons per year to 15 M gallons per year, with a mean of 10 M gallons per year.

PWRs may treat equipment drain water in the boron recycle evaporators, but the equipment drain wastewater may also be combined with floor drain water and treated in the liquid waste processing system. The processing of the liquid waste is typically performed by filtration and ion exchange. The treated waste is currently discharged because of the boric acid content that is not effectively removed by ion exchange (see new ATG Boron selective system). The PWR plants split between those that use vendor processing services and those that have purchased the vendor equipment and operate it with in-plant personnel. The filtration step in the processing train may involve the use of (a) activated carbon, (b) throwaway cartridge filters and (c) ion exchange beds performing the filtration and the ion exchange step. PWR processing can generally be characterized by relatively high curie releases because of the poor filtration by these three methods and larger ion exchange resin solid waste volumes because of the loading of particulate matter on the resins which reduces the capacity of the resins. In the PWR segment, the range of volumes processed by plants is from 0.5 M gallons per year to 5 M gallons per year, with a mean of 2 M gallons per year.

There are numerous problems with current systems, which represent opportunities for new solutions. The biggest drivers are high cost of radioactive waste disposal, personnel exposure and effluent quality. Because of the high volume of liquids to process, BWRs have cost as the principle driver, with dose second and quality of the effluent third. While PWRs are sensitive to the cost as well, final effluent quality, specifically total curies released is perhaps a larger concern. Politically there is a lot of pressure to reduce curie releases from the plant. In order to be in the top quartile as defined by INPO, a plant must continually lower the curies discharged. This is putting pressure on the plants to reduce curie discharges from the plant.

BWRs: The ATG Advance Filtration System has been pilot tested at both Dresden and LaSalle and, as a consequence of this testing, has been shown to be effective for BWR waste, including the difficult-to-filter, floor drain wastes. Success is defined as relatively large volumes of waste water processed per cubic foot of solid waste generated by the filter (i.e., lower solid waste volumes) and increased removal of colloidal cobalt and other particulate matter as compared to the existing precoat filtration used by most BWRs. The pilot testing also demonstrated the recoverability of the filter cartridges following the backwash step, which is also an important element in the definition of success. Because of the potentially large savings in disposal costs of the solid waste, virtually all BWRs that process floor drain waste by precoat filtration and ion exchange should be candidate clients for this service.

The filtration technology can be a stand-alone service, where the in-plant ion exchange equipment would continue to be used. It can also be offered in combination with ion exchange equipment provided by ATG, where ATG tailors the media used in the equipment to match the specific floor drain chemistry for maximum use of the media capacity.

The major selling point of the new filtration technology is the substantial savings in solid waste volume disposal costs (typically 1000 to 1500 cubic feet per year). However, a second selling point of this new technology, if it is coupled with ion exchange, is that it is not as radical a departure from current processing technologies as is perceived with new technologies such as RO and even Ultrafiltration.

PWRs: Like the BWRs, the ATG Filtration System has also been pilot tested successfully at several PWRs such as Commonwealth Edison's Byron plant. The testing demonstrated: (1) long run lengths, (2) recoverability of the cartridge filters after backwash and (3) large removal efficiencies for colloidal particles. Ultimately, these characteristics would normally translate into lower solid waste volumes as compared to existing processing systems that use activated carbon, cartridge filters or ion exchange resins for the filtration step. However, the volume reduction may not be large because of the difference in the filtering characteristics between the ATG system and the existing filtration step. The existing filtration steps are generally fairly poor at removing small and colloidal particles and perform more as a coarse filter as compared to the ATG system which is fairly efficient at removing these smaller particles.

This means that the ATG system is taking more particles out of the water and as a result has shorter run lengths than if it removed only larger particles like the other filtration techniques. However, the better filtration job by the ATG system will probably result in fewer curies being discharged to the environment, which is one of the major selling points of the ATG system. If this feature can be achieved, and at a smaller solid waste volume (although it will not be as large as the solid waste volume reduction for the BWRs), which will offset the cost for the better filtration system, utilities have indicated an interest in the better filtration.

Because of the reduced curies discharged to the environs and probably smaller solid waste volume generation, all PWRs could be potential candidates for the ATG filtration system. The principle driver here is curie reduction to achieve higher INPO ratings (i.e., to be in the top quartile). The incentive for a utility to pursue the approach of coupling the filtration system with ion exchange processes depends on the specific chemistry and radionuclide content of the plant's waste water.

Technology Overview

The Advanced Water Processing System (AWPS) has the potential for widespread success on a worldwide scale in both PWRs and BWRs. The AWPS incorporates both the advanced features (patent pending) of Advanced Filtration and Advanced Ion Selective Technologies (patented). The AWPS includes:

- Advanced Filtration System (AFS)
- Advanced Organics System (AOS)
- Advanced Ion Selective System (AISS)
- Advanced Demineralization System (ADS)

Typical problems encountered in current filtration systems include: (1) poor effluent quality, (2) short run lengths on filters, (3) frequent filter change-outs/backwashes, (4) large waste volumes, and (5) failed filter cartridges. The AFS features reduced waste production per million gallons of water processed, cleaner water for recycle or release to the environment, filter element volume 100 times less than that of competitive filters, and a far lower capital cost compared to systems with similar performance.

Typical RO problems include: (1) increased cleaning frequency, (2) fouled RO membranes, (3) intermittent operation, and (4) reduced flux rates.

Advanced water processing is being applied using a broad range of tools to solve specific problems. These include backflushable filters, UV/oxidation, and ion selective resin and pressurized demineralizers. However, the core to making all these things possible is the improvements made in the filtration. Up-front filtration is necessary to minimize waste and to give some of the other technologies an opportunity to perform in the environment for which they were intended. Another technology being used by ATG to improve performance is the use of ion selective resins. While this technology is not always unique, the improved filtration step makes this approach much more viable and is part of the system being proposed for Commonwealth Edison and others.

Because of the nature of the fluid streams being processed, particularly floor drains, it is necessary to have a good filtration process up front to protect the rest of the system from the trash that is often included in the water being processed. The problem is that in a radioactive system, filter change-outs result in high personnel exposure and high waste and, therefore, need to be minimized. Therefore, it is desirable to have a backflushable filter with the following characteristics: long periods of time between backflushes, few filter changes, and good water quality. To accomplish this, ATG has tested numerous commercially available filters and selected the best. Next, a process was developed to make backflushable filters backflushable at a reasonable cost, while producing high quality effluent.

This is done by feeding chemical additives into the water upstream of the filters. An algorithm has been developed that meters the concentration of the additives based on measuring the conductivity and turbidity of the water. These chemicals cause the small particles to clump together forming larger and larger groups of particles that are easily filtered and furthermore can be easily backflushed. Testing has illustrated 100-fold increase in the volume of water processed during a filtering cycle, prior to having to backflush. Filter life is extended 5 to 10 times and effluent activity is reduced 3 to 5 times

These filters are combined with a system for injecting a polyelectrolyte and a proprietary additive (Chem Add Skid). The polyelectrolyte causes the particle to agglomerate. This has been described as making particles the size of marbles and marbles the size of basketballs. Having large particles improves the filtration step and the effectiveness of the backflush process. The backflush operation is performed by flushing the filter directly into a High Integrity Container (HIC) for subsequent dewatering. This is another benefit since the backflush stream does not have to be further processed as with UF or RO. The preferred embodiment of the design may include multiple filters. Control of the system is based on measuring two parameters (conductivity and turbidity). Additional additives may be injected at a constant amount, while the polymer injection is based on the measurement of the parameters mentioned and an algorithm developed as part of the testing to date. In addition to testing, hydraulic modeling is done in retrofit situations to assure the backflush operation of the large filters compared to the test filters. This modeling has already been done with the standard design.

Everything is commercially available. The patent application covers the combination of a back-flushable filter with chemical additives and the process for determining the ratio of these additives and how it is controlled. So, the key is to have a properly designed backflushable filter, the mix of chemicals, the control, and the field experience with the equipment and process.

Performance

Testing on the AFS began in late 1996 and continued through 1997 and 1998. The original filtration tests were carried out on the so-called LaSalle Pilot Filter Test Skid shown in Fig. 1. Actual tests were first done at Dresden and confirmed at LaSalle with this unit. The skid was manually controlled and allowed the testing of three filter types.

Early bench- and pilot-scale data for the Dresden plant are shown in Tables I–VI. Some 139 runs show excellent run times and turbidity reductions. Actual runs were carried on on floor drains, equipment drains, and chemical waste waters. Table VII illustrates pilot-scale tests from Dresden with full-scale averages and totals for throughput gallons. The full-scale equivalent of nearly 5 M gallons was treated. The pilot testing conducted at Dresden suggests: (1) run lengths of 300,000 gallons between backwashes (100-fold improvement) and (2) cartridge lives of approximately 6 months to a year (5- to 10-fold extension). Efficiencies in removing colloidal particles have been improved as evidenced by an effluent activity reduction of 3 to 5 times. Waste volumes have been dropped significantly. In the case of LaSalle, waste volumes are expected to drop by a factor of 6 to 7 from the present levels.

The resulting Chem. Add. Skid of the 30 gpm full-scale system has been designed, fabricated, and delivered to Byron. A complete 60 gpm Advanced Water Processing System (AWPS), including the AFS, AOS, AISS, and ADS subsystems has been designed for LaSalle and is shown in Fig. 2. This system offers (1) reduced water processing costs of ~$400,000 annually, (2) reduced resin volumes of ~1200 ft3/year, (3) 100% recycle of treated wastes, and (4) fixed cost, turn-key operation for processing water and disposing of resins. The cation exchange unit operations sequence, degassifier, and anion vessel sequence were all designed to reduce the resin waste volumes.

Table VIII shows test results from Ontario Hydro's Bruce Nuclear Station and further illustrates the type of improvement reported above. These were bench tests using the same source of water for both tests. This was also used for the pilot-scale testing. Pilot-scale testing illustrated similar results, as illustrated in Table IX. Without pretreatment, seven backflush cycles were run and the total throughput was 284 gallons. With pretreatment, seven backflush cycles were run and the total throughput was 4,959 gallons It is interesting to note that the last cycle with pretreatment had a throughput of 242 gallons which is 85% of the total (seven cycle) performance without pretreatment. The 4,959 would scale up to a total flow of 1,174,000 gallons. In addition, this test arrangement was not the optimum arrangement. The optimum arrangement would be to have a different filter arrangement. ATG estimates this would be a further performance enhancement of 2 to 3 times. This estimate is based on other testing which shows the effectiveness of the multiple filter approach. A full-scale Chem. Add. Skid has also been designed and specified for Ontario Hydro and is currently under final design review at the site. It is very similar in configuration to the Byron skid.

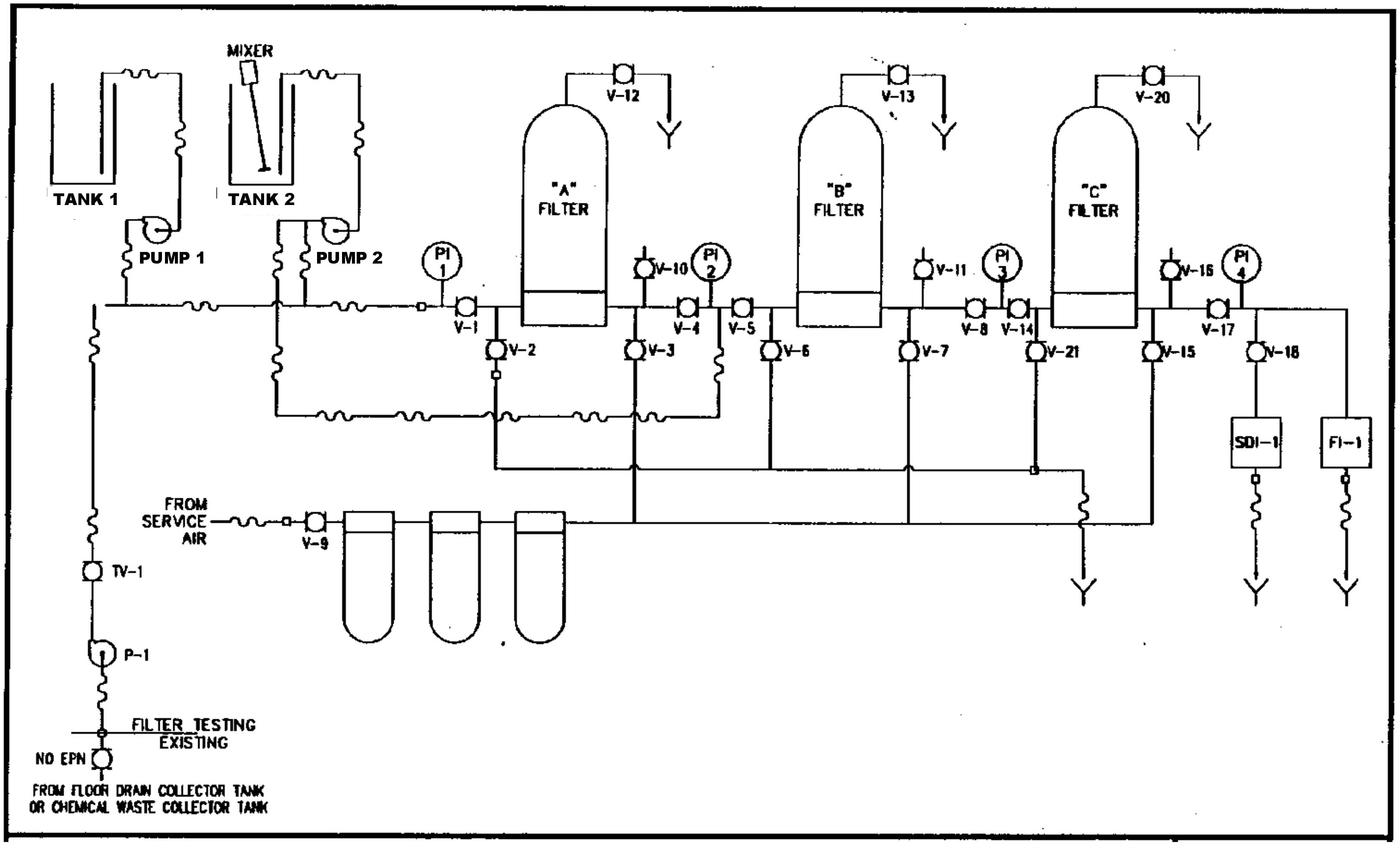

Figure 1. LaSalle Pilot Filter Test Skid.

Table I. Dresden Bench-Scale Test Data

	Date	Conductivity (μ mho)	Turbidity (ntu)		Chem. Add Dose (ppm)	TOC (ppm)	Comments
			Influent	Effluent			
Avg.	2/24 – 4/10/97	158.75	57.09	0.40	Constant	5.573	16 Runs

Table II. Dresden Test Data Intermediate Filter

	Date	Runtime (min.)	Conductivity (μmho)	Inf. Turb. (ntu)	Eff. Turb. (ntu)	Chem. Add 1 (ppm)	Chem. Add 2 Dose (ppm)	Gallons	Comments
Avg.	8/25–29/97	4.5	41.9	115.2	2.39	Constant	Constant	9.5	28 Runs
Total								263	

Table III. Dresden Test Data Course Filter #1

	Date	Runtime (min.)	Conductivity (μmho)	Inf. Turb. (ntu)	A Eff. Turb. (ntu)	Chem. Add 1 (ppm)	Chem. Add 2 Dose (ppm)	Gallons	Comments
Avg.	9/3–5/97	5	173	144	35.29	Constant	Constant	9.41	17 Runs Inf. Turb. 450 ntu @ skid
Total								160	System Eff. Turb. 3.4 ntu

Table IV. Dresden Test Data Course Filter #2

	Date	Run Time (min.)	Conductivity (μmho)	Inf. Turb. (ntu)	A Eff. Turb. (ntu)	Chem. Add 1 (ppm)	Chem. Add 2 Dose (ppm)	Gallons	Comments
Avg.	9/8/97	9	284	178	0.75	Constant	Constant	18.25	4 Runs
									Inf. Turb. 400 ntu @ skid
Total								73	System Eff. Turb. 0.19 ntu

Table V. Dresden Test Data Course Filter #3

	Date	Run Time (min.)	Conductivity (μmho)	Inf. Turb. (ntu)	Eff. Turb. (ntu)	Chem. Add 1 (ppm)	Chem. Add 2 Dose (ppm)	Gallons	Comments
Avg.	10/6–7/97	24	16	100	0.61	Constant	Constant	88.38	8 Runs
Total								707	System Eff. Turb. 0.23 ntu

Table VI. Dresden Test Data Intermediate to Fine Filter B

	Flow Rate	Dose Rate (MR/Hr)	Conductivity (μmho)		Turbidity (ntu)		TOC (ppm)		Filter Size		Comments
			Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	A Inf.	B. Eff.	
Avg.	2.21	2.12	123.8	121.4	51.5	0.19	5.86	0.31	Constant	1	27 Runs
Avg.	2.20	3.07	179.3	171.0	63.1	0.33	4.85	3.17	Constant	2	38 Runs
Avg.	2.12	1.5	143.3	143.3	66.0	0.16	13.58	NA	Constant	3	3 Runs

Table VII. Pilot Scale Test Results from Dresden

Mostly Floor Drains, Some Equipment Drains and Chemical Waste

Run Number	Turbity	Full-Scale Throughput (Gallons)	
1	75	246000	Average
2	75	210000	203,333
3	75	155000	
	Total	610,000	
4	63	299000	New Cartridge
5	60	139000	
6	88	255000	
7	88	219000	Average
8	200	89000	159,429
9	200	68000	
10	200	47000	
	Total	1,116,000	
11	47	544000	New Cartridge
12	47	489000	
13	33	889000	
14	33	429000	
15	73	519000	
16	33	264000	Average
17	33	709000	347,714
18	19.4	327000	
19	19.4	82000	
20	19.4	62000	
21	78	327000	
22	78	41000	
23	78	28000	
24	78	158000	
	Total	4,868,000	

Table VIII. Ontario Hydro's Bruce Nuclear Station Test Result

Time (minutes)	Filter No Pretreatment Differential Pressure	Filter Pretreated Differential Pressure
0	2.1	1.2
5	6.0	3.5
8.25	25.0 (end of test)	—
10		3.7
15		3.7
20		4.9
25		4.9
30		5.7
35		7.0
40		14.2
45		13.6
50		12.6
55		12.2
Effluent Turbidity	0.12 NTU	0.06 NTU

Table IX. Ontario Hydro Pilot-Scale Results

Filter Element No Pretreatment			Filter Element Pretreatment		
Backwash Cycle	**Throughput (Gallons)**	**Projected Full-scale Throughput**	**Backwash Cycle**	**Throughput (Gallons)**	**Projected Full-scale Throughput**
0	137	24,500	0	1,754	321,000
1	75	13,400	1	1,520	278,000
2	31	5,500	2	452	131,000
3	40	7,200	3	462	134,000
4	33	5,900	4	212	62,000
5	33	5,900	5	252	73,000
6	27	4,800	6	360	105,000
7	26	4,700	7	**242**	70,000
Total	402	71,900	Total	**4,959**	**1,174,000**

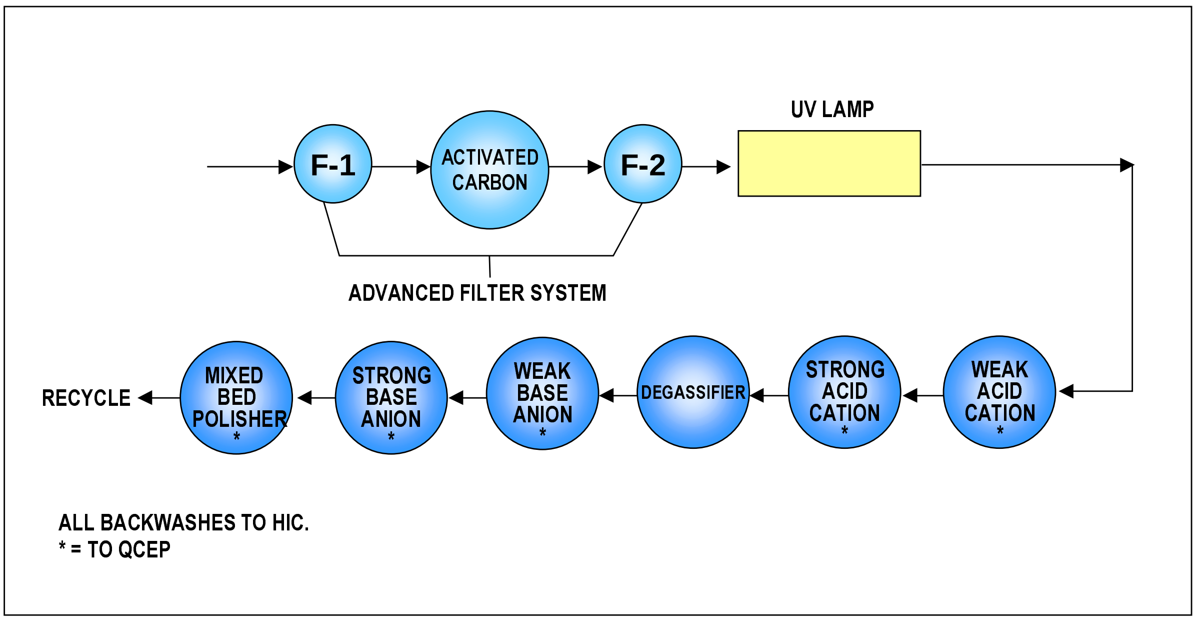

Figure 2. ATG Advanced Water Processing System.

Conclusion

Some specific testing has already been discussed in the performance section to illustrate the type of performance achieved. To date, bench-scale testing has been performed at a total of 8 BWRs and 3 PWRs. Pilot testing has been performed at 2 BWRs and 2 PWRs. All the testing has been successful and has been used to develop the control algorithm. In general, the key feature is the ability to recover about 85% of the first runs initial throughput in following runs. This compares with a typical filter of about 10%.

Testing of the overall AWPS has been successfully completed in the U.S. at the Byron (PWR), LaSalle (BWR), and Dresden (BWR) nuclear plants for Commonwealth Edison and at the Bruce Stations in Canada for Ontario Hydro. Because testing has been on full-size filter elements, scale-up of the filter performance itself is not an issue here.

In all cases, the testing demonstrated (1) long run lengths (300,000 gallons between backwashes—a 100 fold improvement), (2) recoverability of cartridge filters after backwash (cartridge lives of approximately 6 months to a year—a 5 to 10 fold improvement in filter life), (3) large removal efficiencies for colloidal particles (reduced discharge curies), and (4) reduced waste volumes (particularly resin volumes). Evaporation and drying has been combined to create a greatly improved process, especially when the customer can send sludges and/or resins to the ATG Catalytics facility in Oak Ridge, Tennessee. Filtration and selective media systems are provided on a service basis (by month or gallon) or sold outright to the utility.

The financial benefits of the AFS are clearly on reduced waste volumes. The savings estimated by one Commonwealth Edison plant is $0.08 per gallon of water processed annually. For a typical BWR, the annual savings are $800K. For a PWR, the annual savings are projected to be $160K. Other benefits include lower personnel exposure, lower activity levels, and the ability to further process the water using other techniques, such as UF, RO, or selective ion exchange to further reduce the isotopes and curies being discharged by the plant.

ADVANCED ION SELECTIVE SYSTEM (AISS)

Background

Typical problems encountered in current demineralization/media systems include build-up, recycle, or bleed of cesium (Cs), cobalt (Co), boron (B) and iron (Fe) in BWRs Cs, Co, antimony (Sb), and boron (B) in PWRs.

The AISS portion of the overall AWPS features specific ion removals rather than brute force techniques such as total demineralization or reverse osmosis (RO), thus offering smaller equipment skids, subsequent reduced capital and operating cost, greatly reduced waste volumes, and less chance of accidental releases/spiking during plant upsets. In the latter, for instance, breakthrough of activity (e.g., Co and Cs) can be captured on an AISS in place as a polisher. Boron leakage into the system can similarly be handled with a specially prepared bed of Boron-selective media rather than having to follow the system up with the expense and complexity of total demineralization or reverse osmosis. While standard anion resin has limited affinity for boron, it will dump it back to the liquid stream (much like a regeneration) when presented with nearly any common anion. Similarly, Sb will be removed (to some degree), and subsequently build up on the anion column or the anion resin of a mixed bed. However, during a plant upset, such as a slug of iodine, the Sb will be stripped, putting the entire inventory back into the system at perhaps the least opportune time. Such selective media can also be added solely to existing, available vessels or to top off existing media.

The object of a selective system here is, as with the AFS, to offer a unique product or service. As mentioned, Sb, Co, Cs, and B are particular aggravations to the PWR utilities, while Fe, Co, Cs, and B remain to be solved in BWRs. The AISS could further be extended to non-nuclear, fossil plants with problems such as arsenic, antimony, selenium, and lead in wastewaters or flyash ponds.

Currently, bench-scale, pilot-scale, and full-scale studies are being carried out at our facilities, or at the client's site, for several BWR and PWR utilities (where larger feed sample volumes are needed or where feed conditions are difficult to replicate).

Performance

ATG has incorporated its patented "antimony specific" media, Ebony T, into its Advanced Ion Selective System (AISS). This helps solve the common problem of antimony (Sb) in PWRs. Antimony is found in a variety of forms, including anionic species and has very little affinity for standard ion exchangers. Ebony T actually has an affinity for the difficult Sb, Se, As series and functions on a redox potential basis. It also has considerable capacity as shown in Table X for some heavy metals such as manganese (Mn), iron (Fe), and cobalt (Co); and to a lesser degree, cesium (Cs). Even for short contact times, good removals are shown for these ions, as well as total activity, over 40 bed volumes for an actual PWR wastewater. Figure 3 presents this data in a breakthrough curve plot and illustrates the affinity series Mn>Co>Sb>Cs. Breakthrough is normally considered to be 40%. This media is also being used as one of the beds for the "cesium" trap (actually Cs, Co, Mn, Sb, and Zn trap) shown later. Ebony T is completely regenerable or disposable after loading.

A similar, and elusive, ion selective problem in both BWRs and PWRs is the selective removal of boron (B) species. Actual Detergent Drain Tank (DDT) skid solution from a BWR plant containing boron from both a PWR and the BWR totaling 6 ppm was fed through a Boron S media column. Boron was removed to less than detectable (<5 ppb) for over 90 bed volumes demonstrating excellent selectivity, especially for drain water, and capacity as shown in Table XI. An excellent decon. factor of over 1200 was achieved.

A "cesium trap" mentioned previously has been developed at the ATG Catalytics facility. This ion selective system, which actually removes Cs, Co, Mn, Sb, and Zn with total activity decon. factors of over 200, would be applicable to any BWR or PWR seeking to reduce curie discharge levels. The pilot test skid houses four ½-inch × 18-inch stainless steel test columns containing four Cs/Co specific media. From this, a production unit was designed using Cesium T media in two parallel 10-inch × 36-inch columns residing in shielded transfer bells for subsequent transport within the plant. Actual water to be treated will be from carryover from the metal bath reactor to the gas handling train (GHT), to the clarifier, and, finally, to the centrate tank (supernate). Table XII illustrates the selective removal of these ions from radioactive resin regenerant solutions, both neutral and acidic. Cesium T effectively removes 99.45 to 99.62% of the total activity from these solutions for 40 to 50 bed volumes with only a 5-minute contact time. Less than a 0.5% breakthrough was evidenced for most of these radioisotopes.

Conclusion

As mentioned, typical shortcomings in demineralizer/media systems include Cs, Co, B, and Fe in BWRs and Cs, Co, B, and Sb in PWRs. Tables X–XII and Fig. 3 illustrate how the Advanced Ion Selective System (AISS) portion of the overall AWPS allows selective removals of recalcitrant species with little or no affinity for standard materials. This can achieve excellent polishing results and lower curie discharges for the plant. It can also prevent build-up or recycle of these metals within the system and costly bleed or release during an upset. Since these media are specific, smaller skids, lower operating and capital cost, and greatly reduced waste volumes can be expected.

Table X. PWR Selective Antimony Removal

Feed: U1 – Waste Hold-up Tank
Media: Ebony T
Column: 1.27 cm × 25 ml (Media)
Contact Time: One (1) minute
pH: 5.1 (Feed)
Affinity Series: Mn, Fe > Co, Ra > Sb > Cs > Ba > U > Sr

			ACTIVITY (pCi/G)									
Sample		**Vol. (ml)**	**%**	**Mn-54**	**%**	**Co-60**	**%**	**Sb-125**	**%**	**Cs-137**	**%**	**Total Activity**
Feed		1000		443.35		1905.00		50.57		181.70		2823.30
Effluent	1	250	1.27	5.64	1.74	33.19	3.34	1.69	0.27	0.49	1.51	42.70
	2	250	2.64	11.70	3.26	62.16	6.17	3.12	1.36	2.47	3.02	85.21
	3	250	3.30	14.62	3.96	75.51	7.30	3.69	4.81	8.74	4.05	114.48
	4	250	3.89	17.26	4.52	86.13	8.58	4.34	10.24	18.61	5.35	151.05

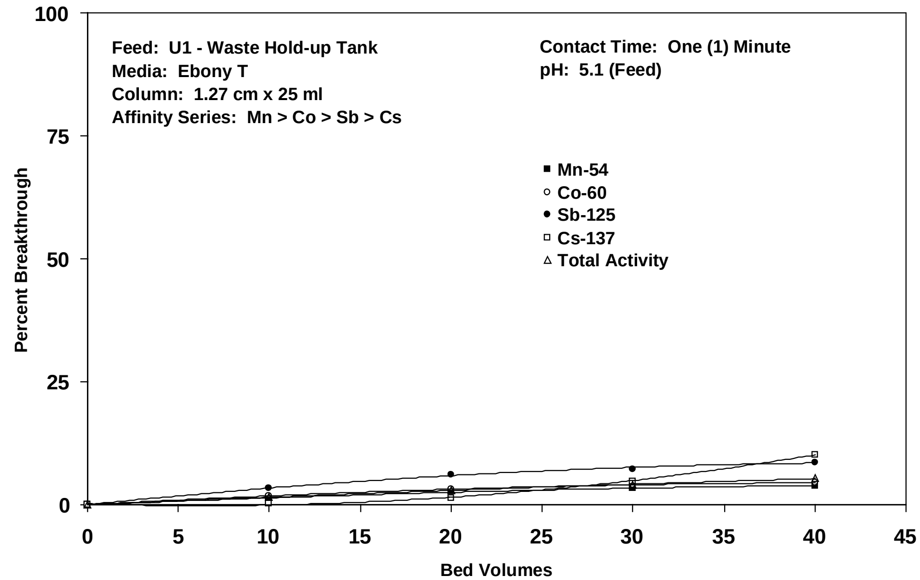

Figure 3. Extraction of Antimony, Manganese, Cobalt, and Cesium on Ebony T Media from PWR U1 Waste Hold-up feed tank.

Table XI. BWR Selective Boron Removal

Feed: Detergent Drain Tank (DDT) Skid
6.06 ppm B (1.32 ppm Fe) (Activity 4.88 E-4)
61% PWR (Heptaborate): 39% BWR (Pentaborate)
Media: Boron S (Macroporous Anion
DVB Tertiary Amino Saccharide)
Column: 50 ml Conditioned Boron S (OH^- Form)
Rate: 5 BV/Hr (250 ml/hr)
1–4 gpm/ft^3 (4–32 BV/Hr)

Contact Time: Five (5) minutes
pH: 6.3 (Feed)
Affinity Series: B>SO4>Cl>HCO3>NO3
Capacity: 0.35 eq/l B (~3 g B/l) (~0.2 lbs B/ft^3)
@ 1 gpm/ft^3
Decon. Factor: ~1000

Sample	**#**	**Vol. (ml)**	**pH**	**Activity (μCi/ml)**	**Boron (ppb)**
Feed		4500	6.3	4.88 E-4	6060
Effluent	1	250	10.2	<LLD	<5
	2	250	10.5	3.76 E-6	<5
	3	250	11.0	1.40 E-6	<5
	4	250	10.8	1.47 E-5	<5
	5	250	10.5	8.63 E-6	<5
	6	250	10.3	<LLD	<5
	7	250	10.2	3.40 E-6	<5
	8	250	10.2	<LLD	<5
	9	250	9.7	<LLD	<5
	10	250	9.7	3.76 E-6	<5
	11	250	9.9	<LLD	<5
	12	250	9.7	<LLD	<5
	13	250	10.4	1.30 E-5	33 [New ICP]
	14	250	10.3	2.78 E-5	14
	15	250	9.3	2.21 E-5	8.3
	16	250	7.3	1.08 E-5	3.8
	17	250	7.2	<LLD	<5
	18	250	7.1	<LLD	<5

Table XII. Selective Removal of Cesium and Cobalt from Resin Regenerant

Feed: Resin Regen. Solutions

Media: Cesium T

Column: ¾" × 50 ml (Media)

Contact Time: Five (5) minutes

pH: Test 1: 7 (Feed)
Test 2: 5.08 (Feed)

Removal: Test 1, 99.45% (Decon. Factor = 181)
Test 2, 99.62% (Decon. Factor = 260)

		ACTIVITY (μCi/ml)											
Sample	**Vol. (ml)**	**%**	**Co**	**%**	**Cs**	**%**	**Mn**	**%**	**Sb**	**%**	**Zn**	**%**	**Total Activity**
• **Test 1** Feed – 1.5 M Calcium Nitrate Regen.	2000		0.68025		0.02522		0.02023		0.06883		0.08391		0.8785
Effluent		0.71	0.0048083		<LLD	0.18	0.00003708		<LLD		<LLD	0.55	0.004846
• **Test 2** Feed – 1.5 M Calcium Nitrate/ 3 M HNO_3 Regen.	2500		1.77214		0.10284		0.05735		0.14805		0.17785		2.2582
Effluent		0.46	0.0081896		<LLD	0.30	0.0001742		<LLD		<LLD	0.38	0.008690