SIX YEARS OF SHORT-BED DEMINERALIZATION AT THE ONTARIO HEALTH SCIENCES CENTRE

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In 1992, TransAlta Energy in co-operation with the Ontario Ministry of Energy and Ontario Hydro, commissioned a cogeneration facility at the Ontario Health Sciences Centre in Ottawa, Canada. At the time the facility represented a number of firsts: (1) The Alberta-based company's first foray into the province of Ontario, (2) the first ever installation of a General Electric LM6000 gas turbine, and (3) the first time that TransAlta purchased a Recoflo® short bed demineralization system.

BACKGROUND

Ontario Health Sciences Centre Cogeneration Facility: The Ontario Health Sciences Centre (OHSC) Cogeneration plant is wholly owned and operated by TransAlta Energy, a subsidiary of TransAlta Corporation. The facility provides 67 MW of power, 26,000 lb./h of 100 psig steam, as well as hot and chilled water to the member institutions of the OHSC, which include the University of Ottawa, Children's Hospital of Eastern Ontario, Ottawa General Hospital, Ottawa Children's Treatment Centre, and the Royal Ottawa Health Care Group. The facility also supplies steam to the National Defense Medical Centre. 42 MW of electricity are provided by one LM6000 gas turbine, with the additional power being supplied by a Foster Wheeler HRSG and an ABB steam turbine.

Design Overview: The procurement and construction of the OHSC facility was coordinated for TransAlta by Delta Projects. The bid specification for the water treatment component called for a system that was capable of producing 120 US gallons per minute of deionized water with a specific conductivity of less than 1 µS/cm, and a silica content of less than 20 ppb. Later on, the silica specification was relaxed to a maximum of 50 ppb. The system was to treat a municipal tap water feed, of which the key parameters are outlined in Table 1.

Table 1: Raw Feed Water Characteristics

Parameter	Reported Values		
	Mean	Max.	Min.
pH	8.7	9.7	6.8
Turbidity (NTU)	0.41	0.94	0.12
Conductivity (µS/cm)	133	171	107
Total Organic Carbon (mg/L as C)	3.12	6.55	0.74
Calcium (mg/L as Ca)	17.5	44.8	3.2
Magnesium (mg/L as Mg)	4.9	11.2	1.4
Sodium (mg/L as Na)	2.6	3.8	1.6
Potassium (mg/L as K)	0.85	0.85	0.85
Alkalinity (mg/L as $CaCO_3$)	25.0	42.0	16.0
Sulfate (mg/L as SO_4)	21.4	28.0	11.3
Chloride (mg/L as Cl)	5.5	12.5	4.0
Fluoride (mg/L as F)	0.94	1.22	0.10
Silica (mg/L as SiO_2)	3.9	6.5	0.0
Design TDS (mg/L as $CaCO_3$)	150		

The mechanical and electrical specifications for the DI system was based on deep-bed co-current ion exchange, with a stipulation that "Other water treatment systems may be offered provided [that] they are able to provide the quality requirement and have [a] proven history."

The bids were evaluated based on two key criteria:

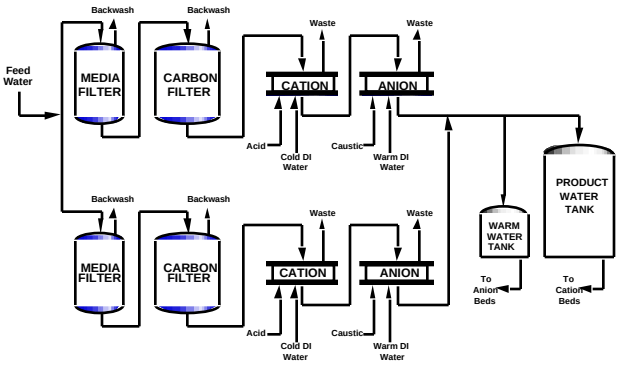
1. the system must fit into the limited available space, and

2. the demineralization process to be selected by the vendor shall be the most cost effective, both for capital operating costs were the lowest, and the system easily fit into the available space.

After reviewing the manufacturers' bids Delta Projects selected the Recoflo Water Deionization System offered by Eco-Tec Inc., Pickering, Ontario, Canada. While the capital cost of the Recoflo system was higher than some of the other systems offered, the amortized capital and operating costs were the lowest, and the system easily fit into the available space.

Two Recoflo trains, each rated at 65 US gpm were provided, along with all the necessary peripheral equipment. A basic flow diagram of the system is illustrated in Figure 1. Each train consists of a multi-media filter for stringent suspended solids removal, a carbon filter for the removal of free chlorine, and a two-bed (cation/anion) Recoflo demineralizer. DI water is collected in a 23,000 US gallon storage tank, which provides the cold dilution water for regeneration of the cation beds. A small warm water tank and plate-and-frame steam heat exchanger were provided to supply warm DI water to the anion beds to ensure silica removal. Each train is controlled by a separate PLC, and both trains are capable of communicating to the plant DCS.

Figure 1: Recoflo Water Treatment System At OHSC



Pretreatment: It has been stated in many previous publications that proper filtration is essential for the smooth operation of any ion exchange system, especially packed bed counter-current systems (Meyers, 1999; Fatula and Muir, 1998). At OHSC, the filtration needs are satisfied by two 36" diameter multi-media filters. Each filter uses five layers of graded media to produce a filtrate with a turbidity of approximately 0.1 NTU.

Following the multi-media filters are two 48" diameter carbon filters. The superficial flowrate through the carbon filters was specified to remove free chlorine only, thus no appreciable organic removal was expected.

Demineralization: The Recoflo demineralizers at OHSC are pictured in Figure 2. Each consists of two ion exchange columns; a strong acid cation column and a strong base anion column. The columns at OHSC are 36" in diameter and 6" deep, giving the demineralizer a much different appearance than other deep bed and packed bed ion exchange systems. The columns are packed with uniform size, fine mesh resin, are counter-currently regenerated, and are completely packed such that no freeboard exists. The benefits of uniform size resins and counter-current regeneration with respect to reduced chemical and rinse water consumption have been well documented in many literature sources, and the lack of freeboard helps to further reduce rinse requirements and ensures that the polishing zone at the bottom of the column is never disturbed.

Figure 2: Recoflo Demineralizer at OHSC

The fine resins used in a Recoflo column are approximately one quarter the size of conventional ion exchange resins. At this size difference, a given volume of Recoflo resin has approximately four times the surface area versus

the same volume of conventional resin, thus the ion exchange kinetics are vastly improved in a Recoflo column. This high amount of surface area is fully utilized in the Recoflo process, as only the exchange sites on the surface of the resin beads are used. This represents no more than 20% of the total exchange capacity of the resin. By improving the kinetics, the flowrates through the column can be significantly increased.

These high flowrates, coupled with the small resin volumes and the low resin loading of the Recoflo process, make for a much shorter operating cycle than a deep-bed ion exchange system. The length of the service run of the demineralizers at OHSC is about 18 minutes at the design TDS. Sulfuric acid and caustic soda for regeneration are drawn directly from bulk storage tanks; there is no need for day tanks. The entire regeneration and slow rinse procedure takes approximately 2.5 minutes to complete. Following the slow rinse, an internal recirculation is performed in lieu of a fast rinse to drain, taking four to seven minutes to complete. The small quantities of effluent wastes from regenerating the beds are sent to a small (1,200 US gal) mixing tank for pH adjustment and disposal.

HISTORY OF OPERATION

Installation and Commissioning: Once commissioning was completed, the systems ran without any significant mishaps for approximately one month. At this point however, it was noted that the time required to recirculate to quality was increasing. As was expected, the high TOC in the feed water resulted in organic fouling of the anion resin.

The organic fouling was remedied by a brine squeeze of the anion beds. However, after four more months of operation, it was noticed that the interval between brine squeezes was gradually becoming shorter. At this point, it was discovered that the hold-up volume of DI water in the warm water piping between the warm water tank and the demineralizers was sufficiently large such that the units were actually being regenerated with cold water. As is commonly known, regenerating the anion beds with warm water aids in organic removal as well as silica removal. To immediately rectify the situation, a pre-heat step was temporarily added to the operating cycle. Shortly thereafter, the piping was re-routed to ensure that the units received warm water for anion regeneration without the preheat step. The commissioning of the system is described in more detail in a previous publication (Jackson et al., 1994).

DI Water Quality: Since the systems were commissioned in 1993, the two deionizers have produced a net total volume of approximately 162 million US gallons of deionized water, or approximately 24.9 million US gallons per year. As of June 1999, Unit A has undergone approximately 56,500 cycles, and Unit B has undergone approximately 41,300 cycles. The reported conductivity and silica concentration in the DI water over a nine-month span from September 1998 to June 1999 are shown in Figures 3 and 4, respectively.

Figure 3: Nine-Month Conductivity Profile of Recoflo Demineralizer at OHSC

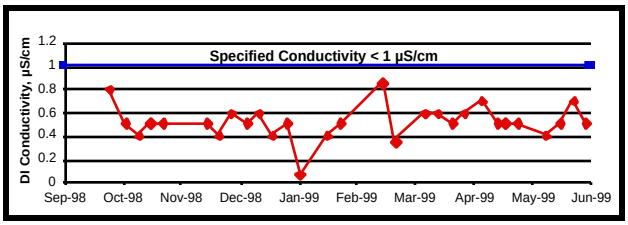
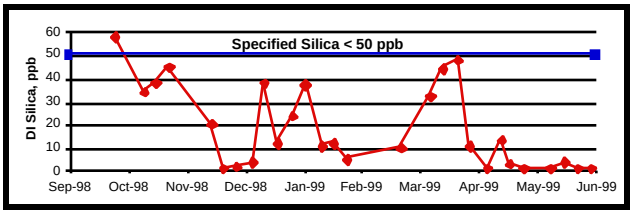


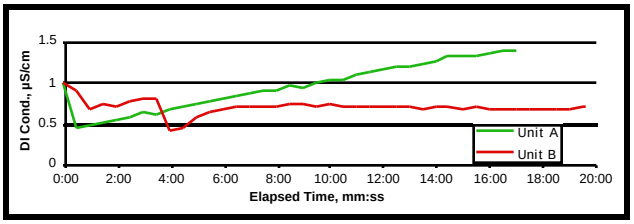
Figure 4: Nine-Month Silica Profile of Recoflo Demineralizer at OHSC



In October 1998, a performance evaluation was made on the systems. The service run of a Recoflo demineralizer is normally controlled by totalized volume, with a conductivity meter serving as a backup to end the service cycle if the conductivity rises above the setpoint prior to the totalized volume being attained. At the time of the visit, Unit B was still performing well, but Unit A was experiencing slightly shortened service runs. To extend the service cycle of unit A, the conductivity setpoint was increased slightly to 1.3 µS/cm. Conductivity profiles of the

demineralizers over one operating cycle are shown in Figure 5.

Figure 5: One-Cycle Conductivity Profile of Recoflo Demineralizers at OHSC, Oct. 14, 1998



The cause of the problem in Unit A was determined to be a reduced salt-splitting capacity of the anion resin due to a combination of organic fouling and the resin having reached the end of its useful life after just under six years or operation. Resin capacity analyses are presented later on in this paper.

Chemical Consumption: While packed bed counter-current ion exchange offers chemical savings when compared to co-current ion exchange, the distinct features of the Recoflo process (fine resins and low loading) decrease the chemical consumption to below even that of other packed bed, counter current systems. In an earlier paper (Jackson et al., 1994), it was shown that the regenerant consumption quoted for a Recoflo system (at a TDS of 120 mg/L as $CaCO_3$), were approximately 10-15% lower than those for a deep bed counter-currently regenerated ion exchange system that included a degasifier.

In October 1998, the chemical volumes were checked to see if the consumption still matched the design specifications. The results are listed in Table 2.

As noted, at the time of the performance evaluation, the resin in Unit A had reached the end of its useful life, causing shortened service runs and in turn higher chemical consumption. However, it can be seen that the performance of Unit B is still essentially the same as the values quoted during procurement of the system.

Table 2: 1998 Chemical Consumption vs. 1992 Proposed Values at OHSC.
Values are Expressed as lb. (100%) per 1,000 US Gallons of DI Product Water. Design TDS = 150 mg/L as $CaCO_3$

	Unit A (Oct. 14, 1998)	Unit B (Oct. 14, 1998)	Design Value
H_2SO_4	3.67	2.92	2.98
NaOH	2.33	1.87	1.91

Maintenance: After the warm DI piping was re-arranged in June 1993, no major piping or mechanical modifications have been required. Brine squeezing of the anion beds for organic removal is performed approximately once every four to six months, when the recirculation time approaches seven minutes. The relatively small quantities of resin allow the brine squeeze procedure to be performed in situ; thus it is a very simple operation, requiring only 4-5 hours of down-time to complete. The over packed state of the Recoflo columns also enhances organic removal, as the compression of the resin helps to squeeze out the entrained organics.

The relatively small size and short operating cycle of a Recoflo deionizer makes maintenance and troubleshooting a much easier task than for deep-bed systems, and this benefit was considered during the selection of the water treatment system at OHSC. Often, a problematic ion exchange system can be remedied by performing one or two manual regenerations. This procedure only takes a few minutes for a Recoflo deionizer, rather than a few hours. Changing the resin is generally regarded as the most significant maintenance procedure that would be performed on any ion exchange column. In a Recoflo column, a complete change out can be performed in 3 - 4 hours.

Since 1994, TransAlta has contracted BetzDearborn to evaluate the overall performance of the system, perform routine maintenance, and analyze the condition of the resin. When asked for his opinion on maintaining and troubleshooting the Recoflo

units at OHSC, the BetzDearborn representative replied:

> "The Recoflo system at the Ontario Health Science Centre Cogeneration Facility has consistently provided make-up water quality that meets or exceeds the boiler specification. The Recoflo system is much easier to troubleshoot than a conventional demineralization system because it takes a few minutes to regenerate - you know quickly whether everything is OK - a lot better than the hours it takes with other systems." (Matys)

A common point of concern for purchasers of Recoflo systems is that the short, frequent operating cycles will cause excess wear of the mechanical components, especially valves and pumps. The valves used in the OHSC system are pneumatically operated, spring-close and double acting diaphragm valves. 39 valves are used among the two trains; 14 on each deionizer, 5 on each media filter, and one for filling the warm DI water tank. Nine pumps are used in total; two centrifugal pumps per train, two gear pumps per train, and one centrifugal pump on the warm DI water tank Table 3 lists the number of valve diaphragm and pump repair kit purchases for each year since the system has been in operation.

Table 3: Purchase Record of Valve Diaphragms and Pump Repair Kits

Year	# Valve Diaphragms Purchased	# Pump Repair Kits Purchased
1993	13	0
1994	6	0
1995	0	2
1996	6	0
1997	3	0
1998	4	0

TOC Removal: The demineralizers at OHSC were never intended to remove the TOC in the feed water down to a guaranteed level. However, during the performance evaluation in October 1998, samples of water were taken throughout both trains to determine the TOC removal capabilities of the system. The results are listed in Table 4.

Table 4: TOC Levels Throughout Demineralizer Trains at OHSC. All Numbers are in mg/L

Sampling Point	Unit A	Unit B
Raw Water Header	2.36	2.36
Media Filter Outlet	2.40	2.16
Carbon Filter Outlet	2.14	2.35
Cation Bed Outlet	2.38	2.32
Anion Bed Outlet	0.06	0.17
Anion Regenerant Waste Outlet	118	135

All samples except the anion waste were taken during the service step of the deionizers. Anion waste samples were taken during the anion regeneration step.

As can be seen from the results, over 90% of the TOC are being removed by the anion exchange beds. As expected, little if any is removed by the carbon filter, since the filter was never intended to remove TOC in the first place.

Resin Life: Over the same period of time and at the same throughput, the resin in a Recoflo column will experience far more service and regeneration cycles than an equivalent deep-bed column. However, this will not result in a reduced resin service life. The low resin loading that contributes to the short cycles also help preserve the resin life. Because the resin is only lightly loaded, it does not undergo the severe swelling and shrinking that occurs when resin is loaded to capacity, thus the risk of breakage is eliminated. The resin is also protected by the filtration system that is ahead of every Recoflo unit. Since most of the solids are removed ahead of the ion exchange columns, the resins are not backwashed, and the risk of resin damage from particulate abrasion is minimized.

In October 1998, a sample of the anion resin in Unit A was collected for analysis. The percent increase in moisture content and percent decrease in total and salt-splitting capacity for new Recoflo anion resin is listed in Table 5.

Table 5: Unit A Anion Resin Analysis, October 1998

Parameter	% Change From New Resin
Moisture Content	Within New Resin Specs.
Total Capacity	26 - 35% Decrease
Salt-Spitting Capacity	66 - 70% Decrease

At the time of sampling, the resin in Unit A had undergone almost six years of service, and over 50,000 operating cycles. New cation and anion resin was ordered and installed in Unit A in early November, 1998.

In March 1999, Unit B began exhibiting similar problems that Unit A had been exhibiting in October 1998. At this time, the resin in Unit B had undergone over six years of service and over 39,000 operating cycles. The anion resin in Unit B was replaced in March 1999; the original charge of cation resin is still in service in Unit B as of June 1999.

Summary

The Recoflo short bed demineralizers at OHSC have consistently provided the specified DI water quality for the six years since start-up. The consumption of regenerant chemicals are still the same as was quoted prior to commissioning, and the life of the resin has met expectations. Ease of maintenance is appreciated by both TransAlta operators and the BetzDearborn representative. All in all, the superior performance and reliability of the Recoflo demineralizers at OHSC have generated a significant savings when compared to deep-bed ion exchange, and has given long-term credibility to the use of short-bed ion exchange for high-purity water demineralization.

References

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