IWC 97-67 Presented to the 58th Annal Meeting International Water Conference, Pittsburgh, Pennsylvania, USA

ION EXCHANGE DEMINERALIZERS: BIG PROBLEMS, SMALL SOLUTIONS

Ken Pandya, AWTS INC., Dallas Teaxas

INTRODUCTION

There are thousands of demineralizer around the world that provide high purity water for boilers, turbines, industrial and commercial processes. Many of these demineralizers are over 25 years old. In almost all cases, raw water composition, flow rates, daily throughput requirement and treated water quality have all changed. Today, these demineralizers are working harder than ever. As expected, the owners are experiencing substantial increase in regeneration chemical costs, increase in waste water volumes, and 08M costs. Such frustrated owners faced with the task of updating their systems often consider retrofitting or replacing the entire system with newer technologies, which may cost even more in the long run.

CASE STUDY

AN INDEPENDENT POWER PRODUCER COMPANY IN NORTHERN CALIFORNIA

An Independent power producer company has recently acquired a cogeneration system in northern California. The cogeneration system includes a three-train demineralized water make-up system, two deaerators and other auxiliary water treatment equipment. The water treatment facility was installed in two phases, over a period of twenty-five years. In early 1970's, two demineralizer trains, train A and B, were installed; each rated at 200 gpm. In 1992, demineralizer train C, rated at 500 gpm, was added.

Raw water analysis has remained relatively steady since its original start-up. Please refer to Table-1 which shows original design values (1970 values) vs. current values (1997 values). The demineralizer system produces an acceptable quality of demineralized water that meets ASME standards for 600 psi boilers. Daily throughput needs have been increased over the past 25 year. The demineralizer performance has experienced a drastic decline in terms of increased regeneration frequencies, cost of regeneration chemicals, waste water volumes, and frequent resin replacement. The water treatment system currently requires around-the-clock attention of three full time operators, in addition to on-going maintenance costs associated with the water treatment system.

In view of these concerns, a decision was made to develop a plan to increase the system reliability while exploring ways to reduce current operating costs. An engineering study was undertaken in early 1997 to investigate the problems with the water treatment system, and propose corrective actions to restore the plant performance.

During the course of investigation, several problem areas were detected, which strongly suggested problems with internal distributors, poor regeneration techniques, and choice of anion resin. In our best engineering judgment, these problems are minor. Most of these problems could be corrected relatively easily, and the system performance could return to equal or better than its original specifications

ION EXCHANGE DEMINERALIZER

The ion exchange system consists of three demineralizer trains (Train A, B and C), each consisting of a cation unit, an anion unit, automatic valves, instruments, and controls. Train A and train B consist of one each cation exchange unit, and one each anion exchange unit. Each cation vessel is 66' dia x 60" straight side, filled with 60 cubic feet of strong acid cation resin.Each anion vessel is 66" dia x 78" straight side, with 80 cubic feet of strong base Type II anion exchange resin. Both train A and B are rated for 200 gpm each, or 400 gpm when operated in parallel configuration. Train C includes a strong acid cation unit followed by a strong base Type-II anion unit. Train C cation exchange vessel is 96" dia x 66" straight side, and filled with 125 cubic feet of strong acid cation exchange resin. The train C anion exchange vessel is 96" dia x 96" straight side, and filled with 190 cubic feet of Type II strong base anion resin.

The rated cation exchange capacity is 18.6 kilo grains per cubic foot when regenerated with 6 lbs of 93% basis sulfuric acid/cubic foot of resin. The rated anion exchange capacity of Type II strong base anion resin is 16.8 kilograins per cubic foot when regenerated with 4 lbs of 100% basis caustic/ cubic foot of anion resin. These capacities are normally derated by equipment manufacturers, to account for capacity decline due to age, equipment factor, etc.

Train A, train B and train C demineralizers are operated independently. The train A cation vessel is taken off line when the train A anion is ready for regeneration. Train B and C are operated in the same manner. Train A and B can be put on the service mode at the same time, however, this is not a common practice. Train A and B demineralizer trains are operated together (as a pair) only during the peak demand, or while Train C is in regeneration.

All trains have provided acceptable water quality during normal operation. On-line instrumentation includes a silica analyzer that shows silica level below 5 ppb on a consistent basis. Treated water conductivity is typically less than 5 micro-mhos.

Operation of the demineralizer system has been changed significantly since its original start-up (Early 1970s for trains A and B, and early 1990s for train C). Currently, train A and B demineralizers operate as the primary demineralizers when the hydraulic demand is in the range of 275-350 gpm, with either train A or train B on service. Train C is put on service only when the hydraulic demand is 275-550 gpm. In other words, Train A and B vessels have been operated at surface loading rates up to 15.6 gpm/square foot, and Train C has been operated at a surface loading rates up to 11 gpm/square foot. Such high flow rates far exceed the recommended operating flow rate of 6-8 gpm/square foot.

A, B, and C train cation exchangers are regenerated at a respective rate of 10.7, 10.7 and 7.3 lbs (93% basis) of sulfuric acid per cubic foot of the resin, as compared to the original intended rate of 6 lbs per cubic foot of cation resin. A, B and C train anion exchangers are regenerated at a respective rate of 6.5, 7.3 and 4.9 lbs of caustic (100% basis) per cubic foot of resin, as compared to the original intended rate of 4 lbs per cubic foot of anion resin. Needless to say, regeneration costs have skyrocketed.

EFFICIENCY OF DEMINERALIZER SYSTEM

Working ion exchange capacity is a real measure of performance of the conventional ion exchange systems. Working capacity is back calculated by using actual gallons of either decationized or deionized water between an average service run, actual chemical dosage rates per each regeneration, and an actual water analysis (expressed as grains per gallon) as a basis of calculations. After computing working capacity for each ion exchange unit, one can compare it with the so-called "book" capacity of a specific ion exchange resin; after derating the resin for equipment factor (approximately 0.9 equipment factor for cation resin, and 0.85 equipment factor for anion resin).

The Table-2 provides a summary of current operating conditions of each cation unit. The Table-3 provides a summary of current operating conditions for each anion unit. These tables also provide a valuable comparison of book capacity vs. actual working capacity, and efficiency of the ion exchange units.

RESIN ANALYSIS

In January 1997, resin samples from all trains were analyzed. The resin analysis provided good information on the condition of the resin, and highlighted areas of concern. The resin analyses showed a substantial decline of salt splitting capacity. The analysis also indicated that cation, as well as anion resins are mechanically strong, as indicated by less than 2% fines, less than 10% cracked beads, and proper moisture content.

Internal distributors for Train A are suspected to have severe problems, since resin capacity as determined by lab analysis for Trains A as well as Train B is very similar, however throughput from Train A is drastically reduced, as evidenced by 85,000 gallons throughput for Train A vs. 120,000 gallons for Train B.

Reduced life of the anion resin is most probably due to the combination of extremely high hydraulic loading rates for trains A and B, frequent regeneration of trains A & B, and high ratio of weakly basic anions in raw water (bicarbonates and silicates). This is particularly a problem for Type II anion resin in this type of application. In fact, the Type-II anion resin in this case behaves as Type I anion resin, except with no benefits of Type-I anion resin.

Further research and consultation with the industry experts provide an insight to the behavior of Type-II anion resin in this particular application. As one can see in Figure-1, 2 and 3, capacity of Type-II anion resin is much higher than the Type-I anion resin at 0-year. The capacity of Type-II anion resin starts dropping rapidly, whereas Type-I anion resin remains fairly stable over useful resin life. Naturally, regeneration costs for Type-I anion resin would be much lower in the long run.

RESTORING PERFORMANCE:
Following corrective steps can be taken to restore the performance of the demineralizer system. Please refer to Table-4 and Table-5 for projected performance of the system, under proper operating conditions. Also refer to Table-6 for operating cost analysis, and Table-7 for projected capital costs for replacing all Train A and Train B internals.

1. Operate Train A and B as a pair, with C train on stand-by; and vis-a-versa. This is an important step to reduce hydraulic load on the resin, and extend the life of the resin. Also, this measure should improve water quality.

2. Replace internal distributors for train A as soon as possible. Monitor performance of Train B closely, and replace train B distributors if performance continues to decline. Internal distributors should be custom-engineered to fit the site specific conditions.

3. Consider switching over to Type-1 anion resin which has a lower ion exchange capacity, however a history of steady performance over the long period, and a better resin life for similar installations.

OTHER CASES

The literature has ample cases which prove that small changes produce big results. Four such cases, discussed in length (IWC 92-20, and IWC 86-55) illustrate the point.

1. Energy systems Inc., (IWC 92-20, Case-A), while experiencing familiar problems with throughput capacities, decided to switch from Stratabed type anion exchange resin to Type II resin, install a recirculating pump to improve demineralizer hydraulic loading characteristics, and change regeneration procedures. The recirculation provided a multi-pass effect to provide more than one stage of demineralization. The results were dramatic. The run lengths increased by 40% as compared to the original design, and treated water conductivity has been reduced by at least 50%.

2. A cogen plant in southwest Texas (IWC 92-20. Case-B), was experiencing problems with short runs due to high silica leakage, mechanical strength of anion ion exchange resin, resin capacity, and organic fouling. At the conclusion of investigative studies, it was determined that an elevated regeneration temperature of 120 Deg. F was the primary problem for the acrylic type anion resin, originally selected to do the job. This particular customer switched over to Type II anion resin, which was found to be more suitable for this application. Number of regenerations were reduced drastically, along with the regeneration chemical costs, and waste water volume reduction.

3. An ammonia and Urea plant in the Midwest (IWC 92-20, case-C) benefited by installing a heater to heat regenerant caustic to 120 Deg F., and silica leakage dropped from 0.2 ppm to 0.025 ppm. When the original Type I resin was switched over to Type II resin, the throughput capacities increased dramatically from its original capacity of 100,000 to 300,000 gallons per train to over 400,000 gallons per train, even in presence of high temperatures.

4. Corpus Christi Petrochemical Company, Texas (IWC 86-55) employed a Type II anion resin. Only after six months of operation, anion exchangers showed unexpected reduction in strong base capacity. This customer decided to switch over from Type II anion resin to Type I anion resin, with remarkable improvement in the resin performance, compared to Type II resin (5% capacity decline vs. 48%+ capacity decline).

SUMMARY

Ion-exchange demineralizers are time tested, proven tools to produce high quality water, however the demineralizer performance can deteriorate due to improper application of ion exchange resins, seasonal changes in the raw water analysis, extreme variation of flow rates, and wrong regeneration techniques. Many times, worn internal distributors contribute to significant decline in the demineralizer performance. Careful site specific engineering evaluation of the demineralizer systems can provide an important insight to the demineralizer problems. Quite often, the cost of fixing a problem is relatively insignificant, as compared to daily operational problems, increase in O&M costs, loss of throughput capacities, and cost of a new systems.

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SEE TABLES ON NEXT PAGES

TABLE-1

RAW WATER ANALYSES

	1970 VALUES		**1997 VALUES**	
	mg/l	mg/l, CaC03	mg/l, Ion	mg/l, CaC03
Ca	12.0	30.0	13.2	33
Mg	7.0	28.8	9.8	40
Na	23.9	52.0	22.0	48.0
K	1.1	1.4	NR	
Total Cations		112.2 (6.56 gpg)		121.0 (7.07 gpg)
HC03	93.9	77.1	100	82
S04	5.0	5.2	6.2	6.5
Cl	18.0	25.4	22.8	32.1 (Calc.)
N03	5.1	4.1	NR	NR
P04	0.3	0.4	0.3	0.4
Total Anions		112.2		121.0
Si02	49.4	41.0	39	32.4
C02	2.7	3.1	3.2	3.6
Tot. Exch.				
Anions		156.3 (9.14 gpg)		157.0 (9.18 gpg)
TDS	218.4		216.5	
Iron	0.5		0.09	
pH.	7.8		7.6	_

TABLE-2

CATION UNITS (CURRENT OPERATION)

CATION UNIT	TRAIN A	TRAIN B	TRAIN C
Cubic feet of resin	60	60	125
Acid dosage, s/cubic foot (back-			
Calculated)	10.7	10.7	7.3
Book capacity, before derating, Kgr/cu ft.			
(Note-1)	22.8	22.8	20.2
Book capacity, after derating (0.9			
equipment factor)	20.5	20.5	18.2
Available ion exchange capacity, Kgr/vessel	1,230	1,230	2,275
Rated throughput per run, gal (Note-2)	174,000	174,000	321,800
Actual throughput per run, gal (Note-3)	96,580	131,580	260,000
Working ion exchange capacity, Kgr/cu ft.	11.4	15.5	14.7
Ion exchange unit efficiency (%)	11.4/20.8 (55%)	15.5/20.5 (76%)	14.7/18.2 (81 %)

Note-1: Based on standard strong acid cation resin. These capacities may vary, depending upon engineering notes published by other resin manufacturers.

Note-2: Based on incoming cation load at 7.07 grains/gallon

Note-3: Computed by adding cation run plus regeneratration water for anion unit & Train C anion unit is regenerated with Train A/B decationized water.

TABLE – 3

ANION UNITS: TYPE 11 STRONG BASE (CURRENT OPERATION)

ANION UNIT	TRAIN A	TRAIN B	TRAIN C
Cubic feet of resin, Type II, strong base	80	80	190
Caustic dosage, lbs/cubic foot (back-			
calculated)	6.5	7.3	4.9
Book capacity, before derating, Kgr/cu ft.			
(Note-1)	18.9	19.3	17.9
Book capacity, after derating	16.1	16.4	15.2
Available ion exchange capacity, Kgr/vessel	1,288	1,312	2,888
Rated throughput per run, gal (Note-2)	140,300	142,900	314,600
Actual throughput per run, gal	85,000	120,000	260,000
Working ion exchange capacity, Kgr/cu ft.	9.8	13.8	12.6
Ion exchange unit efficiency (%)	9.8/16.1 (61 %)	13.8/16.4 (84%)	12.6/15.2 (83°/6)

Note-1: Based on standard Type 11 strong base anion resin. These capacities may vary, depending upon engineering notes published by other resin manufacturers.

Note-2: Based on incoming anion load of 9.18 grains/gallon

TABLE-4

CATION PERFORMANCE (PROJECTED)

CATION UNIT	TRAIN A	TRAIN B	TRAIN C
Cubic feet of resin	60	60	125
Acid dosage, lbs/cubic foot (back-			
Calculated)	7.3	7.3	7.3
Book capacity, before derating, Kgr/cu ft.			
(Note-1).	20.2	20.2	20.2
Projected capacity, after derating	18.2	18.2	18.2
Available ion exchange capacity, Kgr/vessel	1,092	1,092	2,275
Projected throughput per run, gal (Note-2)	154,400	154,400	321,800
Current throughput	96,580	131,580	260,000
Throughput: (projected /current) x 100	160%	117%	123%
Current acid dosage, lbs/cubic foot	10.7	10.7	7.3
Projected acid decease	32%	32%	0

Note-1: Based on ResinTech CG8 strong acid cation resin. These capacities may vary, depending upon engineering notes published by other resin manufacturers.

Note-2: Based on incoming cation load at 7.07 grains/gallon

Note-3: Computed by adding cation run plus regeneration water for anion units. Train C anion unit is assumed to be regenerated with Train A/B decationized water.

TABLE -5

ANION PERFORMANCE. TYPE-I STRONG BASE (PROJECTED)

ANION UNIT	TRAIN A	**TRAIN B**	**TRAIN C**
Cubic feet of resin, Type I, strong base	80	80	190
Caustic dosage, Ibs/cubic foot	5	5	5
Book capacity, before derating, Kgr/cu ft.			
(Note-1)	14.9	14.9	14.9
Book capacity, after derating	12.7	12.7	12.7
Available ion exchange capacity, Kgr/vessel	1,016	1,016	2,413
Projected throughput per run, gal (Note-2)	110,700	110,700	262,800
Current throughput	85,000	120,000	260,000
Throughput, projected /current * 100	130%	92%	101%
Current caustic dosage, lbs/cubic foot	6.5	7.3	4.9
Projected caustic decease (increase)	23.1 %	31.5%	(2%)

ote-1: Based on ResinTech SBG1P Type I strong base anion resin. These capacities may vary, depending upon engineering notes published by the resin manufacturers.
Note-2: Based on incoming anion load of 9.18 grains/gallon
Note-3: Based on the assumption that internal problems are corrected.

TABLE-6

OPERATING COST ANALYSIS

	CURRENT, $/YEAR	**FUTURE (PROJECTED), $/YEAR**
ACID + CAUSTIC	$ 248,500	$ 173,500
CATION + ANION RESIN	$ 32,200	$ 18,700
REPLACEMENT		
TOTAL ANNUAL	$ 280,700	$ 192,200
OPERATING COST		
ANNUAL OPERATING COST		$ 88,500
SAVINGS		

NOTE:
1. Acid cost is computed at 6 cents/lb, 93% H2S04 basis.
2. Caustic cost is computed at 21 cents/lb, 100% NaOH basis.
3. Chemical regeneration costs are weighted average basis: Train A: 40% on-line, train-B: 30% on-line, train C: 30% on line.
4. Cation resin replacement cost: $ 50/cubic foot. Cation resin life is 3 years or more.
5. Anion resin replacement cost: $125/cubic foot. Type-II resin life is 1.5 years based on actual operating experience. Type I resin life (projected) is 3 years or more based on similar installations.
6. Based on 183,960,000 gallons per year (350 gpm average) through put

TABLE-7

CAPITAL COST RECOVERY

INTERNAL DISTRIBUTORS, SCH. 80 PVC (TRAIN A/B ONLY)	$ 25,000
SIMPLE PAYBACK	LESS THAN 4 MONTHS

Phone (972) 733-4404 or Email: ken@awtsusa.com