A COST EFFECTIVE APPROACH TO SILICA REDUCTION

Busch Goncarovs
Connecticut Yankee Atomic Power Company
East Hampton, Connecticut 06424

Richard D. Doyle
Associated Technologies, Incorporated
Charlotte, North Carolina 28281

ABSTRACT

Silica, in and of itself is a relatively inocuous substance which provides no hazard to the environment, nor to plant systems which remain at ambient temperatures. However, when system temperatures and pressures are increased during power production, silica can combine with cations to form a zeolite layer on fuel assemblies, eventually creating the potential for fuel failures which lead to higher activity releases to the environment, increased production of radwaste, and greater potential for radioactive contamination thereby increasing plant radiation levels. Because of these potential problems maintaining minimum levels of silica in plant systems that are in contact with the fuel is essential.

Removal of silica from systems can be accomplished through several means. Ion exchange resin may be used, however, proper conditions must exist for this to be effective. Draining and refilling of tanks provides marginally effective relief, provided no other chemical, such as boron, would need to be replaced and the radwaste system is capable of processing the waste generated. The two most effective means for systems which must maintain some chemical constituency are the bleed and feed and reverse osmosis (RO) processes. Deciding which method to pursue requires evaluation for each individual case. In the case of the Spent Fuel Pool (SFP) at Connecticut Yankee, it was determined that reverse osmosis would be the most cost effective approach. This was the judgement based on both the economics of processing the SFP water and in keeping with minimizing the volume of radwaste generated.

BACKGROUND

During the first fifteen years (1968 1983) of power operations, Connecticut Yankee used an evaporator to reclaim spent boric acid from the primary system. This acid was then stored in a Boric Acid Mix Tank, used to provide acid to various other tanks and the spent fuel pool. In 1983, while responding to cloudy water in the refueling cavity, it was determined that colloidal silica was present in the cavity at a relatively high concentration. Further investigation revealed that silica was also present at various other points in the system. As a result, an aggressive silica reduction program was instituted in an effort to reduce silica concentrations to acceptable levels while maintaining a cost effective attitude with respect to radwaste production.

Initially bleed and feed of some of the smaller volume systems was used to meet the needs for silica reduction. However, when it was determined that the 350,000 gallon SFP would need to be cleaned up other methods were evaluated and proposals for processing were reviewed. Connecticut Yankee's evaluation showed that RO processing of the SFP would cost less and produce much lower quantities of radwaste requiring processing. Based on this Connecticut Yankee decided to proceed with SFP silica reduction using the reverse osmosis system designed, installed and operated by Associated Technologies, Inc. The systematic completion of the silica reduction from the entire plant took two years to complete, yet the goal of maintaining cost effectiveness was not compromised. The RO processing required approximately two months, including setup and teardown, of this two year program and successfully completed the silica reduction in the plant.

The largest volume of water requiring silica reduction was the spent fuel pool. Early evaluation estimates favored reverse osmosis over bleed and feed by a factor of three, considering boric acid replacement and waste water processed. The initial cost effectiveness evaluation was proven by actual operation to be correct, and the project remained within the budgeted allotment as well as on schedule with an overall cost savings achieved of approximately $200,000.

Radwaste volumes produced as a result of this process were 30 cu. ft. of resin and about 150,000 gallons of concentrates. In comparison, the feed and bleed operation would have created approximately 135 cu. ft. of resin and over a million gallons water requiring processing. Thus from a radwaste reduction prospective, RO processing of the SFP was a very prudent approach.

PROCESS COST EVALUATION

The costs associated with the silica reduction project had to be analyzed such that the proper decision could be made as to how to proceed with the program. The costs associated with bleed and feed were determined as per Table I and had to be compared with costs for leasing an RO

System using the present costs of boric acid and waste processing.

In leasing an RO system there would be some additional costs which would be incurred. These costs were calculated in parallel to the bleed and feed operation for a line-by-line as well as overall cost comparison.

As can be seen, it was determined that the estimated costs if an RO System was used would be a factor of two less than the bleed and feed operation. The savings were mostly in the waste processing and boron replacement costs primarily because the reverse osmosis unit would produce much less liquid waste to be processed. An added benefit to this reduction of liquid waste was that less demand would be placed on plant processing systems and overall plant operation. Actual costs for the RO processing were as estimated and therefore approximately $200,000 was saved in comparison to Feed and Bleed.

RADWASTE PERSPECTIVE

As part of the overall decision making process the impact on radwaste from the two processes under consideration had to be evaluated. Connecticut Yankee has previously terminated the use of evaporators for wastes due to the increasing cost of solidification. Since the majority of liquid wastes could be processed through ion exchange resins, provided the resin was managed properly, and that the overall volume of radwaste was reduced, this was the preferred processing method; therefore, it was not necessary to evaluate solidification costs.

At the time, an average run of the radwaste ion exchanger (capacity 40 cu. ft.) was approximately 500,000 gallons throughput. Since boron and silica would compete for the available exchange sites, it was expected that some reduction in throughput would be experienced. The comparison of the two processes was extended to include the amount of potential radwaste resin used. This also favored reverse osmosis, much like the cost benefit analysis. Bleed and feed would potentially create 120 ct. ft. of waste resin, based on amount of processed water alone, where the total reverse osmosis concentrate stream would not expend one charge of resins. Even assuming one charge would be expended, reverse osmosis compared favorably.

When all the radwaste item were considered, it was possible to list the pros and cons of each process. Once this list was developed, the decision was obvious that reverse osmosis was the prudent path to pursue. The pros and cons are shown in Table II.

REVERSE OSMOSIS (RO) SYSTEM

The system provided by ATI for removal of colloidal and dissolved silica from the SFP consisted of the following components:

TABLE I

Cost Analysis Comparison.

		Feed & Bleed	Reverse Osmosis
1.	Waste Water	1,400,000 gal[1]	150,000 gal[2]
2.	Cost to Process Waste[3]	$350,000.00	$ 37,500.00
3.	Boron loss to be Replaced	41,600 pounds	8,914 pounds
4.	Cost to Replace Acid[4]	$ 41,600.00	$ 8,914.00
5.	Other Costs a. RO Lease Costs	—	$140,400.00
	Total Estimated Costs[5]	$391,600.00	$186,814.00

Notes:

1. Feed and bleed requires a turnover of the spent fuel pool of four volumes, causing a waste volume of 1.4 million gallons.
2. RO System concentrates will be discharged to radwaste processing. With a typical rejection rate of 10% for double pass, a waste volume of 150,000 gallons is generated.
3. Cost to process radwaste is estimated to be at $.25 per gallon.
4. Cost to replace boric acid is estimated to be $1.00 per pound.
5. Costs for makeup water is not included.

TABLE II

Comparison of RO vs Bleed & Feed.

Feed & Bleed:

Advantages:

1. Can be done in-house
2. No plant modification necessary

Disadvantages:

1. Time consuming
2. Great increase in radwaste generated
3. Large amounts of makeup water and boron required.
4. Total cost incurred

Reverse Osmosis:

Advantages:

1. Quick and efficient
2. Small amount of radwaste produced
3. Minimum makeup water and boron needed
4. Less cost
5. Vendor operated.

Disadvantages:

1. Vendor supplied
2. Some modifications may be necessary

- Sluiceable Demineralizer
- Feed Pump Skid*
- Cartridge Filter
- Booster Pump Skid*
- Reverse Osmosis Skid*
- Flexible Hosing for all interconnections

* skid mounted units included all valves, piping, wiring, instrumentation, and controls

ATI provided the labor to install and operate the system and for dismantling and boxing up of the components for shipment offsite at completion of processing. Connecticut Yankee provided the connections, utilities shielding and support in unloading, loading, decontamination, and movement of the equipment, and health physics and chemistry support as required.

The system as installed was designed to take suction from the recycle loop of the SFP directly through the sluiceable demineralizer to the suction of centrifugal feed pump. Use of this demineralizer was required because connections were not available on the SFP demineralizer discharge line. This sluiceable demineralizer effectively reduced the activity levels in the RO system thereby limiting exposure to the operator. The feed pump increases system pressure and pumps the SFP water through the cartridge filter where particles 2.0 micron or larger are removed. This filter effectively prevented fouling of the RO permeators by suspended solids or resin fines. Following the cartridge filter, the borated SFP water flows to the suction of the booster pump which increases the pressure to approximately 450 psig for processing through the RO permeators.

The RO unit is a two-stage system of hollow fiber membranes. The hollow fiber membrane is its own support structure. Hollow fibers as small as the diameter of a human hair (about 100 microns) are produced as tubes with all thickness making up one half of the diameter. Their design has the structural strength analogous to a 2" pipe with a 1/2" wall thickness. These fibers are bound together as U-tubes with the open ends potted in a an epoxy tube sheet. The bundle is then encased in a pressure housing. The water is distributed from the center of the tube bundle. As it flows over the fibers, some penetrates the fibers, flows down the bore of the fiber, and is collected at the tube sheet end of the vessel and is discharged back to the SFP. The remainder of the water carries the concentrated salts to the concentrate outlet of the vessel. The concentrate from the first stage of the reverse osmosis unit is passed through the second stage for additional separation. The final concentrate, about 10% of the feed flow, is discharged to the radwaste system. The simplified flow diagram is shown in Fig. 1.

The three skids, sluiceable demineralizer and cartridge filter were installed in the ground floor elevation of the Spent Fuel Building. The area used was the truck bay and decon area for this temporary installation. The sluiceable demineralizer, a 36" diameter vessel was placed in the back corner to take advantage of shielding provided by walls and a transfer cask. Additional shielding was provided during operation as dose levels on the vessel surface increased. The remaining skids and components were placed on the accessible side of the available area so that personnel could operate the process equipment and take routine readings while minimizing radiation exposure. The operators work station was located an additional distance away behind building walls but close enough to maintain surveillance on the equipment.

PROCESS OPERATIONS

Setup of the RO system went very smoothly from the time the equipment was received onsite until the system started up. This was mainly due to the cooperative effort between Connecticut Yankee and ATI personnel allowing the setup to be completed and processing started within two weeks. This time also included qualification and training of operators for access to the area.

As shown by Fig. 1 the system was placed in the spent fuel pool cooling train by the use of utility prepared connection and isolation valves placed into cooling pump suction lines. Reinforced hoses were used for interconnections between these connections and the unit and return of the permeate. Waste concentrate was sent to the Spent Fuel Building sump to eventually be processed in the radwaste system. Technical and safety evaluations were prepared by station engineers in compliance with station procedures prior to system installation.

The silica level in the spent fuel pool started at 11.7 ppm and was reduced to 0.484 ppm by completion. Approximately 150,000 gallons of concentrated waste water had been rejected to the waste processing system, and the boron rejection and silica rejection rates were averaged 14.3 and 86.4 percent respectively. At one point, the silica rejection rate dropped to 85%. When this was investigated, it was found to be a direct result of increasing pool temperature caused by shutdown of the SFP coolers which were then returned to service. Once the pool temperature was reduced, the rejection rate returned to normal.

Nearing the end of the processing, even though the silica rejection rate was satisfactory, silica levels in the spent fuel pool did not show the normal decrease. In fact, silica concentrations would increase overnight while the RO System was not operating. It was determined through sampling that the Spent Fuel Demineralizer was actually throwing silica as a result of the pool silica being reduced. The ion exchange resin was discharged and refilled with new resin and

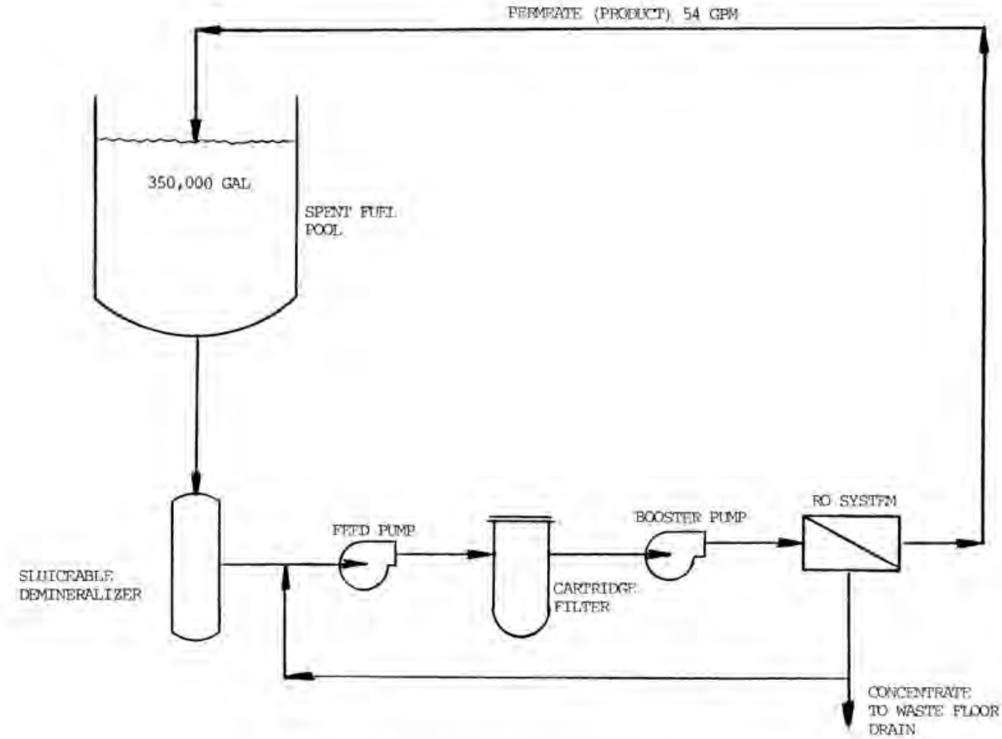

Fig. 1. ATI Reverse Osmosis System.

the processing continued for two additional weeks further reducing the silica levels to the final value.

Based on cost considerations, and an emergency need for the RO System at another facility, it was decided to stop processing at 0.484 ppm of silica in the pool which is above the original target of .200 ppm silica but well below the plant limits of 1.0 ppm. The final process totals are delineated in Table III. The dismantling of the system went smoothly and no contaminated areas were produced as a result of the overall process.

SUMMARY

The silica reduction program followed at Connecticut Yankee was successfully maintained within a budget figure as well as keeping the goal of radwaste minimization realized. The use of the reverse osmosis unit supplied by ATI provided the necessary assistance to realize the goals set by station policy with respect to costs and generated wastes and achieve desired chemical control.

Overall cost savings when compared to the bleed and feed method of approximately $200,000 were realized by this approach. The additional benefits were that there was no impact on station operations while the processing was ongoing and the volume of liquid radwaste generated was minimized.

TABLE III

Comparison of Projected Versus Actual Processing Values.

	Predicted	Actual
Silica concentration in pool (ppm)	.200	.484
Total gallons processed	1,500,000	1,497,873
Total gallons to waste	150,000	149,000
Average Silica Rejection Rate	85%	86.4%
Average Boron Rejection Rate	20%	14.6%
Total Pounds Boron Used	8,914	12,500 (1)
Total Time Processing	4 weeks	6 weeks (2)
Solid Waste Produced (ft^3)	30	30 (3)

NOTES:

(1) Boric acid added to spent fuel pool to maintain refueling concentration as per FDSA analysis.

(2) Time includes processing holds due to rainwater causing waste hold up system to go above administrative limit set for reverse osmosis processing (three days), and changeout of spent fuel pool ion exchanger (one day).

(3) Resins from the sluiceable demineralizer.