HOLLOW FIBER FILTRATION --
AN ECONOMIC FILTRATION SYSTEM

Robert L. Harkins
HPD Incorporated
Naperville, Illinois

Jim Small
Union Electric Company
Calloway Nuclear Power Station
Fulton, Missouri

ABSTRACT

The Callaway Nuclear Power Station #1 of Union Electric has had problems obtaining satisfactory filtration of its condensate polishing regenerate waste streams. The initial condensate filter system did not meet the discharge requirements; a second cartridge system met the requirements but with high replacement costs and labor costs. Therefore, alternative filters were investigated and two were selected to be tested in parallel with the existing cartridge filters.

Test operation of a non-precoat backwashable permanent type hollow fiber filter was tested successfully and showed very favorable operating/replacement costs, projected long life, minimum backwash volumes and low backwash rate.

INTRODUCTION

This paper discusses the process description, Hollow Fiber Filter (HFF) development, test data and results, and economics of the hollow fiber filter system. Also, evaluation of this filter as tested on low TDS and High TDS will be presented.

This is the first Hollow Fiber Filter unit to be placed in operation in the U.S. Several other systems have been tested in Japan and Taiwan and put into commercial operation in Japan.

With this Hollow Fiber Filter, the volume of drummed material is limited to the crud only, since these filters are replaced very infrequently and can be incinerated when expended. Effluent quality was such that it more than met the NPDES discharge permit requirements.

With a life of two-three years before replacement, the exposure rate to an operator is near zero, since there are no items to be maintained nor inspected.

BACKGROUND

Union Electric's Callaway Nuclear Power Station Unit #1 is a 1150 MWe PWR facility located in Callaway County, Missouri and was one of the original SNUPPS designs. This facility went into commercial operation in December 1984 and has maintained very high onstream reliability throughout the operation of the plant.

The plant is located near the Missouri river from which it intakes water and discharges clean water within the NPDES guidelines. The NPDES guidelines require that suspended solids effluent be limited to a daily average of 7.1 pounds per day suspended solids and a maximum of 10.7 pounds per day from the outfall number 001 of the plant. In order to satisfactorily meet these discharge requirements on the blowdown side of the condensate polishing beds, suspended solids filtration was required (Fig. 1).

UNION ELECTRIC COMPANY
CALLAWAY NUCLEAR POWER STATION NO. 1

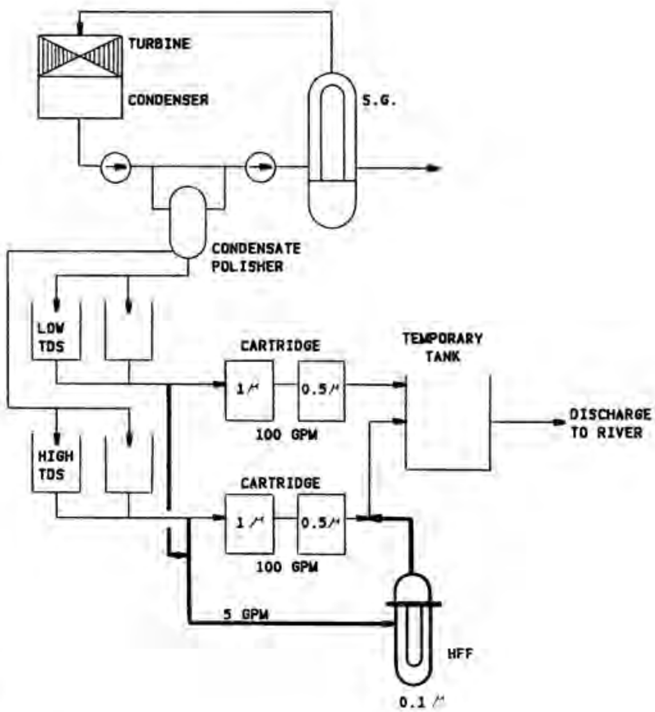

Fig. 1. Condensate Polishing Regenerating System.

DEVELOPMENT OF THE HOLLOW FIBER FILTER

Toshiba Corporation is a primary contractor and constructor of BWR & FBR plants in Japan. Toshiba developed their own exclusive radwaste test facility where certain radwaste and nuclear technologies are produced for market to both Japan and ultimately to the world. One of the areas for improvement was in the radwaste area, in particular requirements for volume reduction. This was especially important with the requirement that all radwaste volumes had to be stored on site for future burial purposes throughout Japan. Thus, it was essential to reduce the volume of buried material to a minimum for both current storage and future burial locations.

In the drive to minimize all waste volumes from the plant, Toshiba noted that the additional waste volume created by the precoat filter media was significant in volume such that volumes up to 10 to 1, in relation to the actual crud removed, were being realized. This excessive volume was an item which could be eliminated and ultimately reduce the burial volume. Therefore, Toshiba through its research group NAIG began the development of the submicron pore Hollow Fiber Filter (Fig. 2).

5 GPM HOLLOW FIBER FILTER

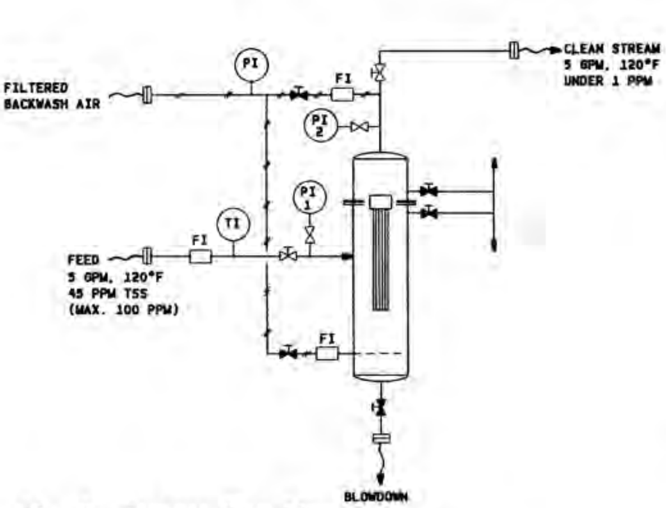

Fig. 2. Process Flow Diagram.

The Hollow Fiber Filter System (HFF) was tested extensively in the laboratory on many different process streams and particle size systems. Based on the nominal particle size distribution for radwaste crud, over 99% of the particles are greater than 0.1 micron (Fig. 3). By capturing this percentage while maintaining a clean effluent and minimum bottoms concentrate volume and long element life (Fig. 4 & 5), the economics in favor of Hollow Fiber Filter. This system after much laboratory testing was tried at TEPCO's 2F-1 & 2 common LCW system. A second test on the condensate polishing system at 2F-1 was also conducted in 1984 and a third test including full operation at H-1, for suppression pool polishing system, was conducted in 1984.

With the successful conclusion of these tests; orders were placed by TEPCO for the supply of HFF units for commercial operation with full size units going into operation beginning in 1984 at K1 and in 1986 at 1F-3 nuclear plants.

The introduction of the Hollow Fiber Filter system in the United States was through HPD who originally supplied the low level radwaste crystallizer to Union Electric at the Callaway Station.

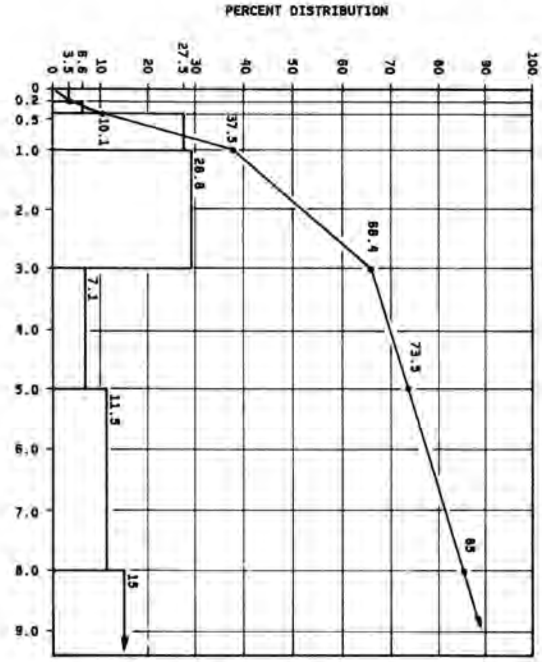

Fig. 3. Particle Size Distribution.

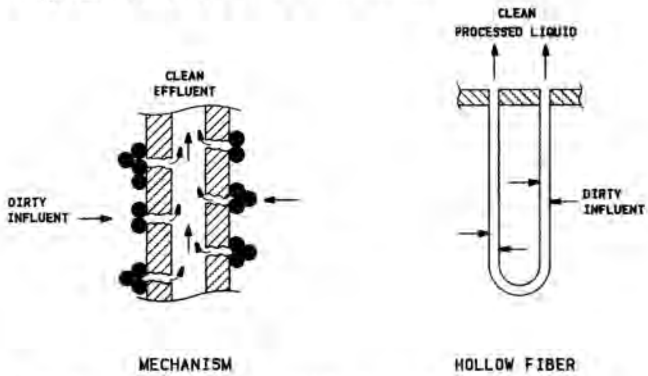

Fig. 4. Hollow Fiber Filter-Principles of Filtration.

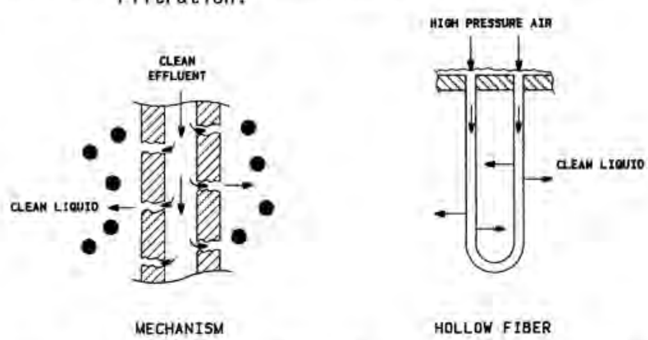

Fig. 5. Hollow Fiber Filter-Principles of Backwashing.

TEST CRITERIA

In August of 1983, the determination was made to discharge Condensate Polisher regenerate waste and

Turbine Building drains to the Missouri River. Implementation of this decision consisted of two steps: Installation of the LRW Discharge Monitor Tanks and the Radwaste Department's research to find a suitable and cost effective filtering system with which to process this waste.

In order to assess filtering requirements, each of the waste streams to be processed must be characterized as to their composition. The waste streams can be broken down into three categories; Low TDS, High TDS, and SLW Drains.

Low TDS is the waste produced during polisher generation from resin transfers, air scrubs, and rinses. It consists mainly of crystalline iron oxides with some diluted chemical wastes and resin fines. The particle size varies from .2 micron upward with the majority in the 0.5 to 3 micron range. The amount of Total Suspended Solids (TSS) varies greatly dependent on plant operating history. This waste is difficult to settle or filter conventionally. Approximately 80,000 gallons of Low TDS are produced per regeneration.

High TDS is the chemical waste produced during condensate polisher regeneration. It is a saturated solution consisting of Sodium Sulfate, Ammonium Sulfate, and non crystalline iron compounds. Total Suspended Solids vary with pH, temperature and on how depleted the resin bed is at the time of regeneration. Approximately 20,000 gallons of High TDS are produced during a conventional regeneration and 30,000 gal per Seprex regeneration.

SLW Drains are waste water collected in the turbine Building from various tank overflows, pump leakoffs, valve leaks, and Cold Lab drains. It consists of dirt, regenerate waste, resin, and oil and grease.

For proper evaluation of filtering needs, a criteria for filter acceptability was established based on past experience and plant needs.

1. EFFLUENT QUALITY-Filter effluent must be of a quality to allow the discharge of an average of one Discharge Monitor Tank daily up to a daily maximum of two Discharge Monitor Tanks under the current NPDES discharge Permit daily mass limits for Outfall 001.

Daily Average--7.1 lb/day requires 8.5 ppm maximum

$$\frac{(7.1 \text{ lb/day})}{(100{,}000 \text{ dal/tank})(8.34 \text{ lb/gal})(1 \text{ tank/day})}$$

Daily Maximum--10.7 lb/day requires 6.4 ppm maximum

$$\frac{(10.7 \text{ lb/day})}{(200{,}000 \text{ gal/tank})(8.34 \text{ lb/gal})(2 \text{ tanks/day})}$$

2. FLOWRATE-The filter system selected must be capable of processing up to 200,000 gal per day. (139 gpm)(24 hrs/day)(60 min/hr)

3. OTHER FACTORS-Also to be considered for a filter selection are initial system costs, annual operating expenditures, waste production, ease of operation, and system maintainability (Fig. 6).

- To eliminate cartridge filters from burial
- Reduce disposal costs
- Reduce maintenance labor costs
- Reduce replacement costs
- Minimize manpower exposure
- Maximize crud removal
- Backwashability

Fig. 6. Objectives of Filter Test.

PRESENT CARTRIDGE SYSTEM CONFIGURATION

To meet initial plant start-up and operation, temporary disposable cartridge filters were installed to meet the filtering needs. These housings contain 80 cartridge elements that are approximately 2- inches in diameter and 30 inches long. The filters are arranged with the upstream filters containing 1.0 micron nominal elements and the downstream filters containing 0.5 micron nominal elements.

There are some advantages to keeping these filters for a permanent processing solution.

1. Low initial system cost-in order to optimize this system for permanent operation, the following modifications would be required:

   a. Relocation of the filter housings

   b. Installation of instrumentation and controls in the Radwaste Control Room. Total $60,000.

2. Should the elements become damaged during operation, it would only require element replacement at a minimum unit cost.

There are also several disadvantages to keeping the present disposable cartridge system.

1. High annual operating cost.

   - $985 per regeneration of disposable cartridge system
   - 182 regeneration cycles per year

   ANNUAL DISPOSAL COST $179,270

   disposable cartridge system is $985. Projected out for 182 Regenerations per year: $985 x 182 regens/yr=$179,270/yr.

2. In the future, these spent elements will require disposal as Radioactive Waste.

   - 120 elements used per regeneration
   - 120 spent elements per drum of waste
   - $300.00 total disposal cost per drum

   ANNUAL DISPOSAL COST $54,600

3. Marginal filtering performance-this system at times limits the volumes discharged due to high effluent TSS (1 ppm to approximately 20 ppm).

4. Undesirable job-it requires personnel to wear safety gloves and lab coats due to the chemical nature of the filtered material. Also, should the elements become radiologically contaminated, it will require PC's for changeouts.

5. High warehouse inventory-requires the warehouse to maintain a high inventory of elements due to the use of 1800 elements per month.

It was because of these significant disadvantages and high costs of the disposal cartridge system that the Radwaste Department deemed it necessary to search for an alternative filtering system. During the testing program, three different filters were tested; a superior replaceable cartridge filter; a backflushable sintered metal, and a backflushable hollow fiber filter.

SUPERIOR REPLACEABLE CARTRIDGE FILTER

The company that provided all of the initial filters in the Radwaste Building were contacted to provide a test filter. The recommended replacement filter consisted of 24 disposable elements of approximately 200 ftø total filtering area. This filter was tested in October of 1984. However, the filter did not filter to the guidelines required and was, therefore, unsuitable for use.

BACKFLUSHABLE SINTERED METAL FILTER

A 1 gpm test unit of a backflushable sintered porous metal filter was provided. A 0.5 micron 316 stainless steel element was used for this test. Testing was conducted on May 10, 1985 with a representative pressent for technical advice. The test was run on Low TDS with a 14.4 ppm inlet TSS and an undetectable effluent TSS. This filter had excellent effluent quality. When a terminal differential pressure of 40.0 psid was reached, the element was backwashed. When returned to service, the element had failed to backwash sufficiently and was backwashed a second time. It was apparent that the element's pores were plugged due to the particle size distribution of the feed. This was confirmed and in order for this type of filter to work on our wastestreams, it would require the use of precoat. Our test unit was not capable of testing with a precoat and future testing would have to be conducted at the supplier's home office. The approximate price for an automated precoat filtering system was placed at $300,000. It would require continuous feed of the precoat and annual operating and maintenance cost projection has not been made. Another disadvantage of this particular filter is accelerated corrosion in the presence of a low pH. Testing of this precoat filter was not pursued due to the trade off of precoat vs. disposable cartridges.

TOSHIBA/HPD HOLLOW FIBER FILTER

A 5 gpm test filter was purchased for testing. This was a backflushable hollow fiber filter that is being used with success in Japan. A test engineer was present for one week of testing commencing on April 7, 1985. The filter ran well with the exception of SLW Drains which failed to backwash off the element. Sampling showed the problem to be oil and grease. The filter was cleaned with TriSodium Phosphate (TSP) and the testing continued. Long term testing was performed by the Radwaste Department through July 15, 1985. During this period of time over 20,000 gal of water was filtered with the effluent quality maintaining 0-0.2 ppm for Low TDS and less than 3 ppm for High TDS, and only a 0.4 kg/sq cm increase in pressure (Fig. 7).

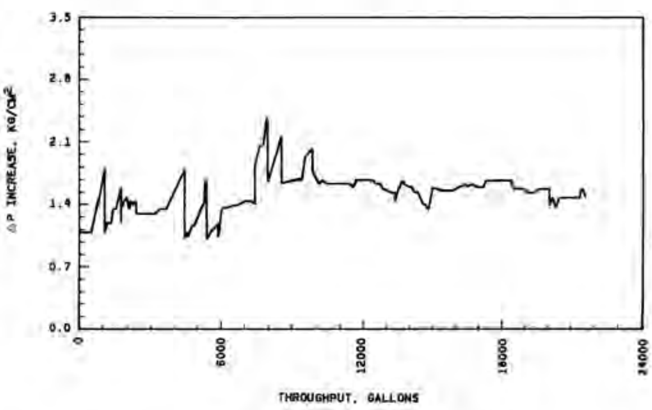

Fig. 7. Total Flow.

Based on the testing program, the HPD/Toshiba Hollow Fiber Filter proved it is capable of filtering High and Low TDS wastes and provided excellent effluent qualities exceeding the minimum requirements. It has also displayed a high resistance to all types of damage (both chemical and physical). With an automated backwash cycle, it should be easy to operate and maintain. The filter system should significantly reduce waste production and, also be very cost effective. Therefore, based upon the successful testing and economics (Fig. 8), the Radwaste Department of Union Electric has purchased an HPD/Toshiba Hollow Fiber Filter System, and Final Phase Separator.

	DISPOSABLE CARTRIDGE SYSTEM	VS.	HFF SYSTEM	
ELEMENT COSTS	1 micron and 0.5 micron	$ 131,000	Two year element annual average replacement	$ 71,000
	Miscellaneous items	$ 4,800		
			Chemicals for cleaning	$ 2,000
		$ 135,800		$ 73,000
WAREHOUSE COSTS FOR MATERIALS @ 10%		$ 13,580		$ 7,300
LABOR	TECHNICIANS:		TECHNICIANS:	
	410 manhours/yr	= $ 10,250	131 manhours/yr	$ 3,275
	HELPERS:		HELPERS:	
	985 manhours/yr	= $ 19,650	10 manhours/yr	$ 200
	1395 manhours/yr	$ 29,900	141 manhours/yr	$ 3,475
WASTE PRODUCTION	182 drums/yr	$ 54,600	18 drums/yr	$ 5,400
TOTAL		$ 233,880		$ 89,175

Annual Realized Savings: $ 144,705
HFF Over Disposable Cartridges

Fig. 8. Projected Annual Operating Costs.