BACKFLUSHABLE FILTER EXPERIENCE
AT THE N REACTOR

Brandon Ball
UNC Nuclear Industries
Richland, WA

W.T. Best, R.C. Keith
Impell Corporation
Walnut Creek, CA

ABSTRACT

The N Reactor is an 4000 MWt, light-water cooled, graphite-moderated reactor located on the Hanford Site in Washington State. A radwaste pilot plant to process plant effluent was constructed in order to maximize future efficiency when a full size radioactive processing facility is built. The pilot plant's purpose is to vary operational parameters such as filtration and ion exchange on a smaller scale to gather as much data as possible.

The input to the pilot plant is radioactive drain lines from the N Reactor. The effluent passes through a backflushable filter and a series of ion exchange columns all scaled down from the future proposed facility. A backflushable filter was selected for this application because of the specific characteristics of the plant effluent and the potential reduced operating costs.

The filter performance has been excellent in terms of filtration of the effluent. Typical total suspended solids in the plant effluent range from 1 to 6.1 ppm; the filter reduces this value to less than 0.1 ppm. In addition to outstanding filtration efficiency, the use of a precoat material, on the filter has resulted in impressive decontamination factors. The filter has been successful in removing up to 50% of the influent activity. An improved performance of several nuclides over other filtration systems has also been achieved. By varying the composition and amount of precoat material on the filter, substantial reductions in waste volumes (and associated operating and disposal costs) have been demonstrated while maintaining a high degree of removal of both activity and total suspended solids.

INTRODUCTION

The N Reactor is a dual purpose production and power reactor that supplies 860 megawatts of electricity for commercial and residential use. The plant is operated for the Department of Energy by UNC Nuclear Industries.

Pilot plant studies have been conducted since May 1986 on the treatment of low-level liquid radwaste effluent from the reactor plant drainage system. The purpose of the pilot testing program was to create a small test facility which would provide continuous process data to assist in the design and optimization of a full scale treatment facility. The new facility will be designed to replace the disposal crib area where liquid radwaste from the N Reactor is currently being sent.

The pilot plant treatment process consists of filtration followed by carbon adsorption and ion exchange. This process was selected in order to maximize removal efficiency while holding regeneration and disposal costs to a minimum. Filtration studies were conducted using a backflushable filter test system provided by Impell Corporation. Carbon adsorption and ion exchange media were tested in a series of individual beds containing 0.50 cubic feet of each material. Figure 1 shows a simplified process flow diagram of the pilot plant. The feed to the pilot plant is the same effluent that will require treatment by the future facility. The flow rate in the pilot plant may be varied from 0.5 to 10 gallons per minute.

The purpose of the filtration step is to act as a prefilter to the ion exchange beds by removing general suspended particulates and activated corrosion products in the feed effluent. The Impell backflushable unit was selected for testing because of its removal capabilities and low volume of waste output as demonstrated on radwaste floor drains at Grand Gulf Nuclear Station (1). The pilot plant runs to date have shown that the overall process of filtration followed by ion exchange is successful in removing suspended solids, dissolved ionic species, and total activity in the plant effluent to very low levels.

DESCRIPTION OF FILTER AND SPECIFIC PARAMETERS

Impell Corporation provides engineering services to the nuclear power industry. In addition to A/E type engineering activity, Impell also provides filtration systems and equipment. New backflushable filter elements developed by Smooth-Pore Filtration Systems Incorporated, along with system simplification improvements designed by Impell, have been undergoing test and demonstration activity at the N Reactor since May, 1986.

The filter elements used are stacked disk smooth pore elements made from corrosion resistant stainless steel or a high nickel alloy depending on the influent. The unique feature of these elements is the smoothness of both the exterior surface of the elements and the micron sized flow passages. These smooth surfaces prevent the accumulation of oil, other organic material, rust and very small particulates. The smooth uniform flow passages, along with the smooth exterior surface, allow the reverse flow of the backflush to remove any material which could impede the forward flow.

Specific design data being established by the pilot plant include flow rate per square foot of element area, micron rating required, backflush pressures and volumes required, filtration performance, particulate decontamination factors, backflush sludge handling and sludge dewatering methods.

As of May, 1986, 39 tests have been conducted. Most of the tests have utilized Ecodex 203H (a 1:1 mixture of cellulose fiber to mixed bed resin); some with precoat and body feed, most with just precoat. The last several runs were performed using Ecocote (cellulose fiber) to compare/contrast differences in operating performance.

Figure 2 is a photograph of the system in place in the pilot plant at the N Reactor. Due to the radiation levels, the filter vessel was wrapped in lead shielding. Specific system specifications are as follows:

Filter elements - Smooth Pore, stacked disk, 316 S.S.

Element area - 2.06 square feet

Backflush - Clean water at 250 psig (nominal)

System Design Pressure - 150 psig

Filter Vessel and Backflush System design pressure - 350 psig

Samples - close coupled filter inlet and outlet sample valves

Continuous exposure of the filter to wastes for the eight months in this installation (and six months in a previous application) (1) has not resulted in any change to the filter clean pressure drop [an impressive factor] or filter performance.

WASTE STREAM CHARACTERISTICS

Low-level radioactive effluent from the N Reactor is transported to the disposal crib area through two pipe lines. The average flow rate for the full scale treatment facility design is estimated to be 650 gpm. The main sources of the reactor effluent are the primary coolant bleed system, fuel storage basin feed and bleed, demineralized water, and filtered raw water. The main composition of suspended solids is principally iron consisting of activated and non-activated corrosion products and precipitates from raw water sources.

The pilot plant is tied into both effluent lines and fed by a small turbine pump. Routine sets of samples (10-20 per run) were taken from the influent to the pilot plant and from the filter outlet and analyzed for activity, radionuclide distribution, total suspended solids (TSS), solid size distribution, turbidity, temperature, conductivity, and pH. A summary of the waste influent characteristics during filter testing is shown in Table I. The activities shown are based on gamma spectra analysis of those nuclides which were most affected by the filtration step.

TABLE I

Waste Influent Characteristics
Filter Runs 1 through 8

Parameter	Minimum	Mean	Maximum
Flow Rate (gpm)	0.6	--	4.0
Temperature (F)	83	91	105
pH	7.2	8.6	9.4
Conductivity (micromho)	50	95	152
Turbidity (NTU)	0.2	0.52	2.6
Suspended Solids (ppm)	0.1	2.0	6.1

	Micron Size		
	1.5-16	16-23	23-53
Solid Size Dist. (%) (based on volume)	30	20	40

Nuclide	Mean Activity (pCi/cc)
Cr-51	15
Mn-54	85
Co-58	4.3
Fe-59	66
Co-60	88
Nb-95	62
Zr-95	46
Ru-103	15
Ba-140	82
Ce-141	59
Ce-144	90

RESULTS TO DATE

There have been eight different runs using the filter, each possessing specific characteristics to acquire test information. Table II details the run specifics such as: the number of backwashes per run, gallons per minute processed through the filter, precoat type and quantity used, whether a body feed step was performed, and the total gallons processed using these specific parameters.

TABLE II

Backflushable Filter Test Runs

Run	# Back-washes	gpm	Precoat	Body Feed?	Gal. Processed
1	5	1.4	Ecodex 203H, 150 ml	No	6158
2	19	0.6	Ecodex 203H, 150 ml	No	5238
3	5	0.6	Ecodex 203H, 600 ml	No	6040
4	6	1.2	Ecodex 203H, 600 ml	No	5630
5	1	4.0	Ecodex 203H, 600 ml	No	5285
6	1	4.0	Ecodex 203H, 291 ml	Yes	4496
7	1	4.0	Ecocote, 150 ml	No	4136
8	1	4.0	Ecocote, 289 ml	Yes	4450

In an effort to understand the data and optimize precoat usage, the information from above was plotted to show the various results of each run in an attempt to correlate and establish optimums for each of the different test variables.

In the figures and discussion that follows, three runs (3, 6, 8) were chosen for further study because they generically characterize the variety of tests performed. Run 3 used a large precoat amount (Ecodex),

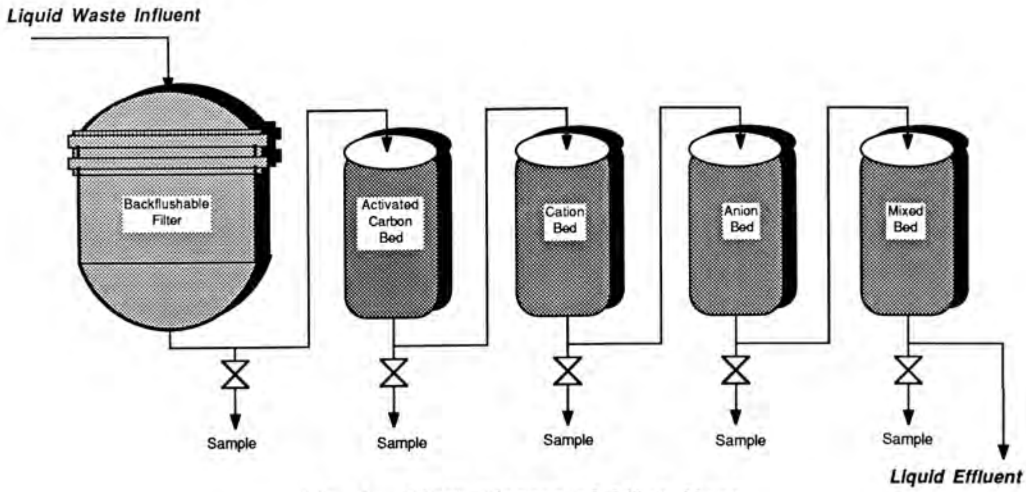

Fig. 1. Block Diagram of Pilot Plant.

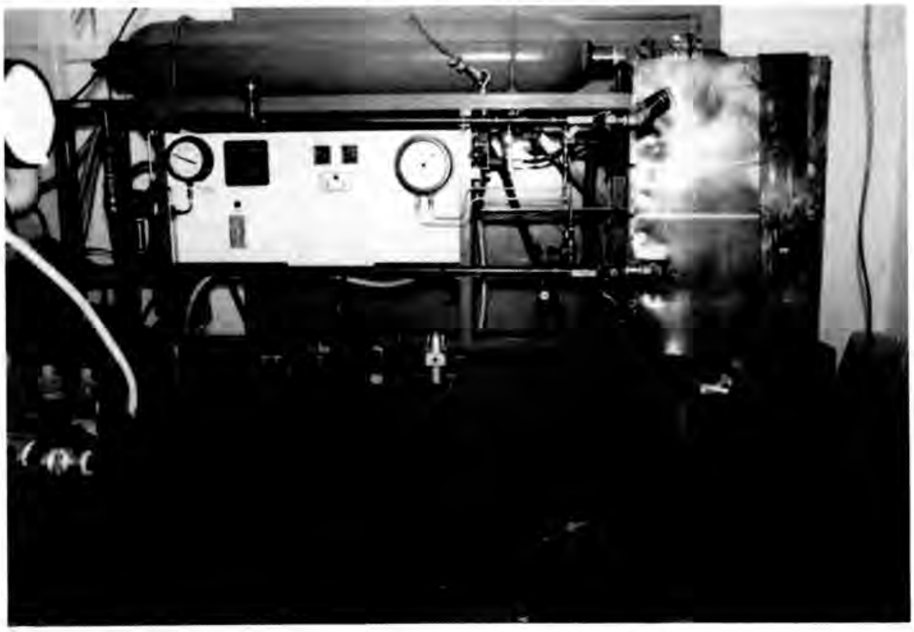

Fig. 2. Backflushable Filter in Place in N-Reactor Pilot Plant.

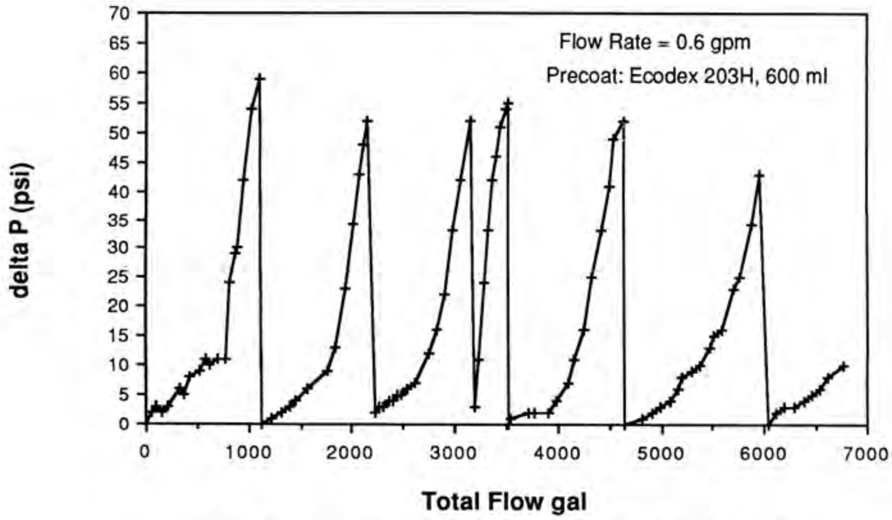

Fig. 3. Differential Pressure vs. Flow for Run 3.

while runs 6 and 8 used a different precoat (Ecodex or Ecocote) and a body feed step.

Figures 3 through 5 detail the filter differential pressure versus the total water processed for runs 3, 6, and 8. The total gallons processed per backwash was higher for both runs 6 and 8 due to the added benefit of body feeding the filter which continually replaces the precoat, thereby increasing the efficiency and processing capability of the filter. In Run 3 the differential pressure was increased to approximately 55 psid. Information on activities of the influent and effluent revealed that iron particulates (mainly Fe-59) were being pushed through the filter precoat at pressures greater than 50 psid.

Another important point that was brought out was the initial short run times achieved based on the total water processed. Specifically, it was found that the dP across the filter increased rather rapidly even though the filter was not collecting a large quantity of dirt. The increased dP made it appear that the filter was becoming plugged on total dirt removed when in fact the precoat was restricting the flow through the filter. The reason for this was that Ecodex, with its ion exchange capabilities, has a charge associated with it when it is first precoated on the filter (positive or negative). As waste is processed through the filter, the Ecodex tends to lose its charge as ion exchange takes place. The precoat begins attracting itself through the run and results in a tighter cake precoating the filter. This essentially chokes off the flow through the filter and the differential pressure (dP) increases.

The amount of precoat required per 1000 gallons of water processed is an important performance parameter that can be compared to other filtration systems and scaled to specific installations. As shown graphically in Fig. 6, the amount required can be as low as 0.02 pounds of precoat/1000 gallons depending on the specific characteristics of the run. Future work at the N-Reactor will include further optimization of the precoat quantity required.

The most significant finding of the filter system was the quantity of activity removed through ion exchange and filtration with the precoat material. The removal of activated corrosion products has been significant. Additional information showed that the filter, with aid of the precoat, had been effective in removing up to fifty percent of the total activity found in the influent stream. For example, Fig. 7 shows the influent and effluent activities of Iron 59 through the filter. As shown, the filter was effective in removing the activity to below minimum detectable activity (MDA) levels.

Table III shows the filter performance evaluated in terms of percentage removal of individual radionuclides for 3 separate runs. Percentages were measured only for those nuclides which exhibited major reduction (greater than 50% in all cases except Ba-140) across the filter. The removal in all 3 runs (and similar results in all runs performed to date) represents between 30 and 50 percent of the total influent activity based on a gamma analysis of isotopes with a half-life greater than 48 hours.

TABLE III

Radionuclide Removal
Filter Runs 3, 6, 8

Nuclide	Ave. Influent (pCi/cc)	% Removal Run 3	Run 6	Run 8
Cr-51	15	*87	*80	*80
Mn-54	85	57	91	88
Co-58	4.3	*93	*90	*81
Fe-59	66	*99	*97	*98
Co-60	88	97	96	*97
Nb-95	62	95	*94	*98
Zr-95	46	*99	*95	*97
Ru-103	15	85	*83	*86
Ba-140	82	23	48	7
Ce-141	59	*95	**	**
Ce-144	90	*92	**	**

*Greater than values due to filter removal to below MDA
**Nuclide was not present in feed during test

Table III also shows that the filter performance in terms of activity removed is not changed significantly by body feeding or by using a non-resin mixture precoat such as Ecocote (refer to Table I for specific run characteristics). Ba-140 may be the only noticeable exception. Ba-140 showed higher removal efficiencies on resin precoat than other non-corrosion products. Tests to date have shown only limited benefit of resin precoat to the removal of dissolved ionic substances. In all runs, the filter has shown a consistently high percentage of removal of TSS (to below 0.1 ppm), turbidity (to below 0.1 NTU), and activities to below MDA limits by the filter.

Table IV summarizes the specific variances associated with each run and includes information such as the precoat required per 1000 gallons of water processed. Table IV also shows that body feeding has extended the run time of the filter. Body feeding and/or the use of Ecocote has reduced the total volume of precoat required per gallon of water processed. This is an important conclusion as a reduction in precoat relates to reductions in volumes of waste for ultimate disposal and burial. This translates into significant cost savings in both precoat costs and ever increasing burial charges.

Finally, Table IV scales up the information to the full size facility which is expected to handle 650 gallons per minute. The amount of precoat required per year as well as the expected precoat cost is shown and are based on a price of $2.75 per pound for Ecodex 203H, and $2.15 per pound for Ecocote. With the limited added benefit of using Ecodex, and the reduced price of Ecocote, precoat charges using Ecocote could be as low as ten to twenty thousand dollars per year. The associated volume of precoat could be as low as 500 cubic feet per year.

CONCLUSIONS

Overall, the filter has been performing flawlessly in terms of a maintenance standpoint. The data to date has shown that the filter is effectively removing all of the total suspended solids from the input stream (to less than 0.1 ppm). In addition, it has been effective in removing up to one-half of the influent activity. Tests have shown that it is possible to reduce precoat amounts without affecting the removal performance thus reducing costs associated with operation and waste disposal.

TABLE IV

Backflushable Filter Performance, all Runs

Run #	Bwash	Precoat ml	Body Feed ml	Total Precoat ml	Precoat lbs	ΔP	Flow Rate GPM	Accumulated Total Flow GAL	Total Flow This Run Gal	----------Precoat/Gallon---------- ml/gal	lbs/1K gal	ft^3/1K gal	Scaled to a Full Size Facility (~650 gpm) ft^3 Precoat/ Year	$ Precoat/ Year
1	1	150	0.0	150.0	0.064	47	1.4	1230	1230	0.12	0.05	0.004	1471	$48,554
1	2	150	0.0	150.0	0.064	48	1.4	2580	1350	0.11	0.05	0.004	1341	$44,238
1	5	150	0.0	150.0	0.064	26	1.0	3755	1175	0.13	0.05	0.005	1540	$50,827
1	6	150	0.0	150.0	0.064	45	1.4	5300	1545	0.10	0.04	0.003	1171	$38,655
1	7	150	0.0	150.0	0.064	5	1.4	6158	858	0.17	0.07	0.006	2109	$69,605
2	8	150	0.0	150.0	0.064	15	0.6	696	696	0.22	0.09	0.008	2600	$85,806
2	9	150	0.0	150.0	0.064	27	0.6	1106	410	0.37	0.16	0.013	4414	$145,662
2	10	150	0.0	150.0	0.064	25	0.6	1537	431	0.35	0.15	0.012	4199	$138,564
2	11	150	0.0	150.0	0.064	25	0.6	2004	467	0.32	0.14	0.011	3875	$127,883
2	12	150	0.0	150.0	0.064	20	0.6	2396	392	0.38	0.16	0.014	4617	$152,350
2	13	150	0.0	150.0	0.064	21	0.6	2768	372	0.40	0.17	0.014	4865	$160,541
2	14	150	0.0	150.0	0.064	12	0.6	2965	197	0.76	0.32	0.027	9186	$303,154
2	15	150	0.0	150.0	0.064	10	0.6	3128	163	0.92	0.39	0.032	11103	$366,388
2	16	150	0.0	150.0	0.064	10	0.6	3301	173	0.87	0.37	0.031	10461	$345,210
2	17	150	0.0	150.0	0.064	10	0.6	3512	211	0.71	0.30	0.025	8577	$283,039
2	18	150	0.0	150.0	0.064	6	0.6	3683	171	0.88	0.37	0.031	10583	$349,247
2	19	150	0.0	150.0	0.064	10	0.6	3827	144	1.04	0.44	0.037	12568	$414,731
2	20	150	0.0	150.0	0.064	10	0.6	4087	260	0.58	0.24	0.020	6961	$229,697
2	21	150	0.0	150.0	0.064	10	0.6	4356	269	0.56	0.24	0.020	6728	$222,012
2	22	150	0.0	150.0	0.064	10	0.6	4530	174	0.86	0.37	0.030	10401	$343,226
2	23	150	0.0	150.0	0.064	6	0.6	4645	115	1.30	0.55	0.046	15737	$519,315
2	24	150	0.0	150.0	0.064	8	0.6	4883	238	0.63	0.27	0.022	7604	$250,930
2	25	150	0.0	150.0	0.064	5	0.6	5066	183	0.82	0.35	0.029	9889	$326,346
2	26	150	0.0	150.0	0.064	8	0.6	5238	172	0.87	0.37	0.031	10522	$347,217
3	27	600	0.0	600.0	0.254	59	0.6	1123	1123	0.53	0.23	0.019	6446	$212,720
3	28	600	0.0	600.0	0.254	52	0.6	2217	1094	0.55	0.23	0.019	6617	$218,359
3	29	600	0.0	600.0	0.254	52	0.6	3194	977	0.61	0.26	0.022	7409	$244,509
3	30	600	0.0	600.0	0.254	52	0.6	4638	1122	0.53	0.23	0.019	6452	$212,910
3	31	600	0.0	600.0	0.254	43	0.6	6040	1402	0.43	0.18	0.015	5163	$170,389
4	32	600	0.0	600.0	0.254	44	1.2	939	939	0.64	0.27	0.023	7709	$254,404
4	33	600	0.0	600.0	0.254	47	1.2	2088	1149	0.52	0.22	0.018	6300	$207,907
4	34	600	0.0	600.0	0.254	46	1.2	2886	798	0.75	0.32	0.027	9071	$299,355
4	35	600	0.0	600.0	0.254	60	1.2	3394	508	1.18	0.50	0.042	14250	$470,246
4	36	600	0.0	600.0	0.254	49	1.2	4406	1012	0.59	0.25	0.021	7153	$236,052
4	37	600	0.0	600.0	0.254	62	1.2	5630	1224	0.49	0.21	0.017	5914	$195,168
5	38	600	0.0	600.0	0.254	46	4.0	5285	5285	0.11	0.05	0.004	1370	$45,201
6	39	150	140.5	290.5	0.123	12	4.0	4496	4496	0.06	0.03	0.002	780	$25,725
7	40	150	0.0	150.0	0.064	47	4.0	4136	4136	0.04	0.02	0.001	438	$11,289
8	41	150	139.1	289.1	0.123	14	4.0	4450	4450	0.06	0.03	0.002	784	$20,222
								Totals	41,111					
								Averages	1054	0.53	0.22	0.019	6369	$209,940
								Averages:						
								based on Run 1	1232	0.13	0.05	0.004	1527	$50,376
								based on Run 2	276	0.68	0.29	0.024	8152	$269,017
								based on Run 3	1144	0.53	0.23	0.019	6417	$211,777
								based on Run 4	938	0.70	0.30	0.025	8400	$277,189
								based on Run 5	5285	0.11	0.05	0.004	1370	$45,201
								based on Run 6	4496	0.06	0.03	0.002	780	$25,725
								based on Run 7	4136	0.04	0.02	0.001	438	$11,289
								based on Run 8	4450	0.06	0.03	0.002	784	$20,222

Note: *Information on specific characteristics of each run is detailed in Table 2*

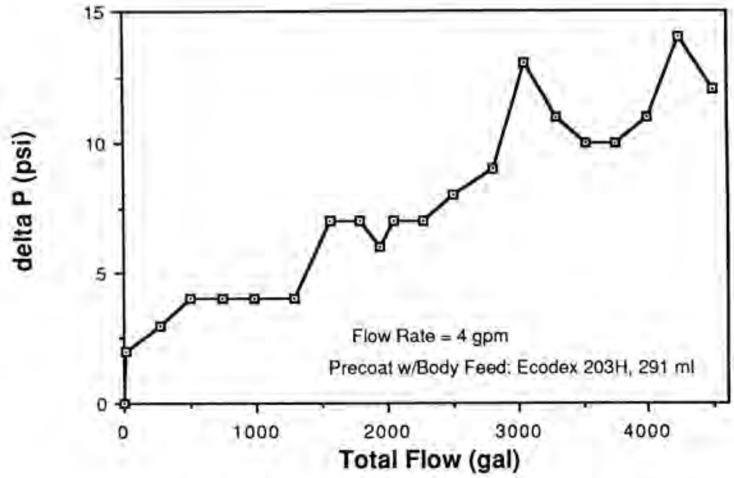

Fig. 4. Differential Pressure vs. Flow for Run 6.

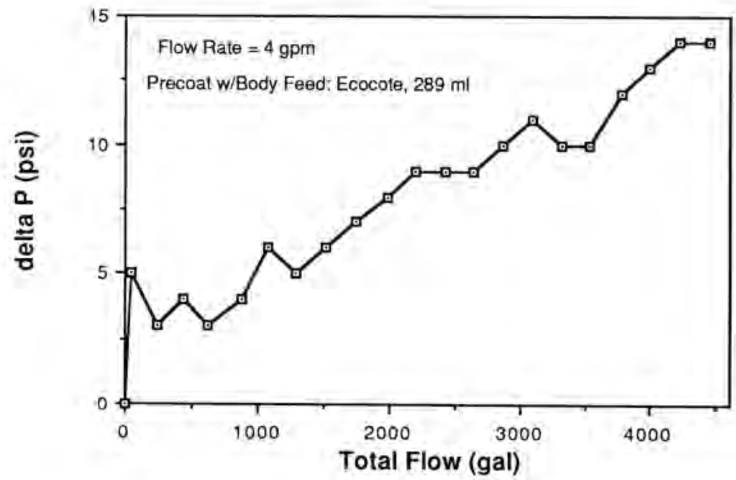

Fig. 5. Differential Pressure vs. Flow for Run 8.

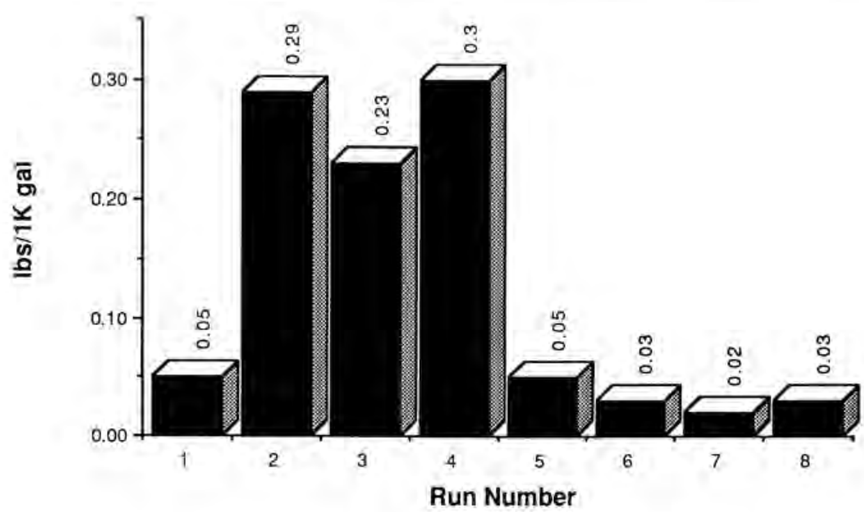

Fig. 6. Precoat Required per 1000 Gallons Processed vs. Run Number.

As the operation of the pilot plant continues, the following tests are being considered to further optimize the filter:

1. Extend body feed runs to completion based on differential pressure.

2. Increase flow rate further to find the optimum point for this test filter. Tests have shown that increasing flow rates help to improve run times without having an affect on removal performance.

3. Minimize further the initial precoat amount and continue body feeding.

4. Research other precoat materials such as zeolite to determine their ability to selectively remove dissolved substances such as Cs-137 from the effluent. Also activated carbon precoat may be used to protect the ion exchange resins in the event of an oil spill up stream of the process.

5. Air drying the precoat and sludge upon backwashing to further reduce disposal volumes.

The data assembled to date has been beneficial in determining a future course of action. Only after further studies can an overall evaluation of the cost effectiveness of using this system and the associated future costs for a full scale facility be properly determined.

ACKNOWLEDGEMENTS

The authors would like to thank Paul J. MacFarlan of UNC for his effort in the complete installation of the pilot plant and his assistance in collecting the voluminous data associated with this project.

REFERENCES

1. M. Michalski, B. Warren, R.C. Keith, J.J. Morley, "Backflushable Filter Tests, Radwaste Floor Drains and Equipment Drains, Grand Gulf Nuclear Station", Waste Management '86 Proceedings.

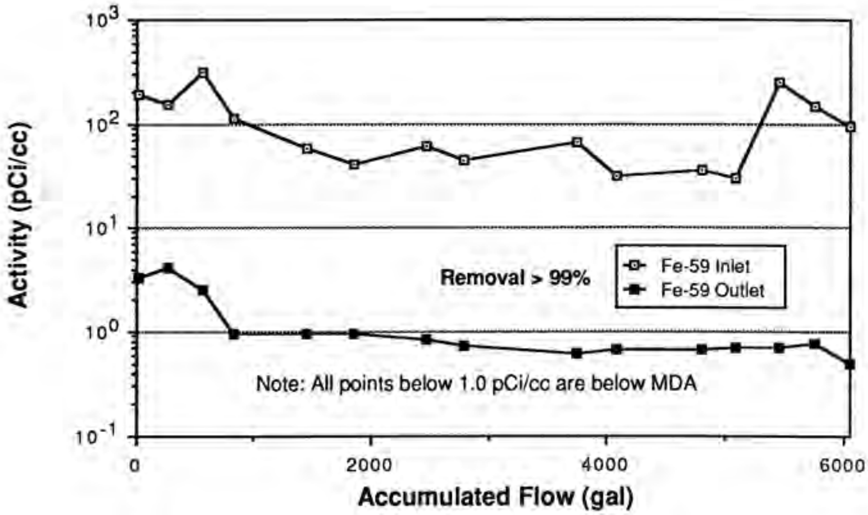

Fig. 7. Fe-59 Decontamination Factor, Run 3.