LIQUID RADWASTE PROCESS OPTIMIZATION AT CATAWBA NUCLEAR STATION

B. E. Cauthen and J. C. Taylor
Duke Power Company

ABSTRACT

Since commercial operation in 1985, Catawba Nuclear Station has experienced significant filtration problems with the radioactive liquid waste system. The performance of the filtration and ion exchange equipment has been significantly worse than other Duke Power stations. Full scale tests have been performed to investigate the causes and potential solutions to the waste processing difficulties.

The initial waste stream characterization study revealed a large percentage of sub-micron particles. This information immediately suggested that the existing filtration equipment was not adequately sized to effectively process the waste stream. New technologies which would effectively enhance the performance of the processing system and reduce both operating and maintenance costs were researched. This included bag filters, depth filtration, custom designed ion exchange vessels and radionuclide specific ion exchange media.

The subsequent full scale testing resulted in a processing scheme which resulted in extended filter life, over 100 percent increase in ion exchange bed life, 90 percent reduction in filter media costs and improved radionuclide removal.

INTRODUCTION

During the past year, Duke Power Company developed a new strategy for the processing of low-level radioactive liquid waste from the floor and equipment drain system at Catawba Nuclear Station (CNS).

The previous processing system consists of a 40 micron absolute cartridge filter followed by 50 and 30 cubic foot ion exchange vessels with a cartridge post IX filter. This system has provided poor performance in terms of filterability, radionuclide removal and ultimately, system operability and maintenance. The continuous inability of this system to perform as intended warranted major change.

Previous Duke Power studies on improved processing have shown that diversifi-cation of materials is necessary for the removal of radioactive contaminants from the process stream (Ref.1). With this knowledge in hand, the focus of the study turned to what particular medias should be utilized on the waste stream at Catawba. The major goals of this study were:

1. Extend filter life to greater than one week.
2. Increase ion exchange bed life by 100%.
3. Reduce filtration operation and maintenance cost by at least 80%.
4. Achieve the following effluent quality:

Co-58	< 5E-5 microCi/ml
Co-60	< 5E-6 microCi/ml
Nb-95	< 1E-6 microCi/ml

FILTRATION STUDY

Media Tests and Performance

The development of improved filtrates began with the characterization of the particle size distribution in the waste stream. The results of the Catawba study were that 99.5% of the actual particles in the waste stream were smaller than 5 microns and 93% were less than 1 micron. This reaffirmed that the existing 40 micron filter was inadequate and that the demineralizer beds were serving both filtration and ion exchange functions.

Inexpensive alternatives to the bulky cartridge filters were researched. Two viable options were carbon bed depth filtration and high efficiency bag filters. The testing of those two new medias was performed in the Waste Solidification Building at CNS over a period of four months. Connections were available to allow the media to be installed in the normal process stream in place of the normal 40 micron filter. This provided typical operating conditions with no interruptions or major modifications to normal plant operations. The timing of the tests included a large portion of a refueling outage which allowed processing with a wide variety of waste stream constituents, including elevated concentrations of the radionuclides mentioned in the test goals.

Several brands of bag filters were tested and rated for total throughput and effluent quality. The most promising results came from the high efficiency bag filters. These bags are 7 inches in diameter and 32 inches in length. The filter is 100% polypropylene with exclusion and efficiency ratings as shown in Table I.

Each model of bag filter was tested in a variety of configurations to determine an optimum arrangement. The 527A and 529A models were the option for the initial filter in the filtration stage of the new processing alignment. The 527A bag displayed the ability to maintain a constant effluent quality while yielding an average throughput of 30,000 gallons prior to exhaustion due to pressure drop (50 psid). The particle distribution previously discussed allowed the filter to remove all of the particles on the large end of the distribution and a small portion of the small particles. The technical data presented in Table I suggests that the 529A would provide greater throughput than the 527A due to exclusion ratings; however, test data revealed that the 527A actually removed more particulate and provided greater throughput. Thus, the 527A was chosen as the system pre-filter.

TABLE I
Bag Filter Technical Data

MODEL #	EXCLUSION (MICRONS)	EFFICIENCY (%)
523A	1.26	91
	1.5	95
	2.5	99
	5.5	99.9
525A	1.26	65
	2	83
	3.5	95
	5	99
	8	99.9
527A	1.26	30
	2.5	50
	5	70
	9	95
	13	99
	20	99.9
529A	5	14
	13	50
	23	95
	32	99
	40	99.9

One goal of the test was to extend filter life for one week or more. The filter design allows for more dirt to be retained if the flow rate is lower. The anticipated normal flow rate is 20 GPM. The 527A filter will hold 760 grams of dirt prior to exhaustion at 20 GPM. Theoretically, if a waste stream containing 400 PPM solids is loaded onto this filter at 20 gallons per minute, it will require replacement after only 30,000 gallons. During testing, throughputs of 30,000 gallons or greater were attained on similar influent water. With four of these filters arranged in parallel, the flow through each filter will be only 5 gallons per minute with 910 grams of dirt holding capacity. This will result in a required changeout after 36,000 gallons per filter or 144,000 gallons total. Figures 1 and 2 show the input solids concentrations and expected throughput for a 527A bag filter at various flow rates. The estimated annual CNS processing volume is approximately 2.1 million gallons which translates to over

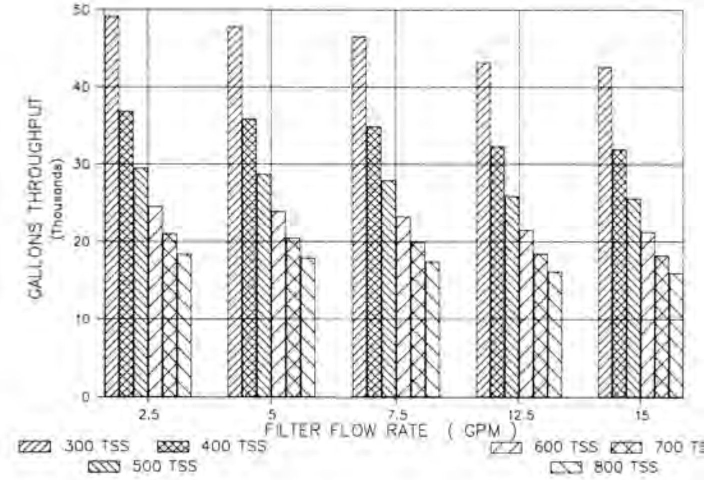

Fig. 1. Catawba Nuclear Station 527A Throughput vs. Flow Rate.

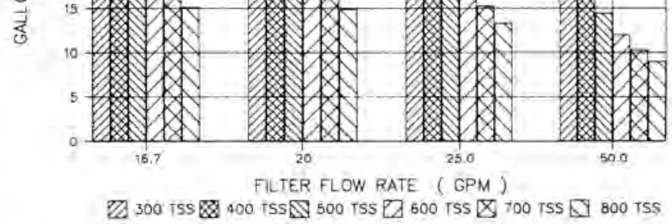

Fig. 2. Catawba Nuclear Station 527A Throughput vs. Flow Rate.1. Catawba Nuclear Station 527A

two and a half weeks of filtration prior to exhaustion due to pressure drop.

The second component tested in the filtration process was a deep bed carbon filter. This filter was in service downstream of the 527A or 529A bag filters. Influent solids were typically in the range of 200 to 400 ppm. The effluent was normally less than 50 ppm and greater than 100 only on the occasion that the depth filter was challenged with influent qualities of greater than 1000 ppm. The effluent data shows that very little decontamination factor (DF) is realized on Cobalt-58 or 60. This result is not surprising due to the apparent size of the Cobalt colloids which have been shown to be less than 0.2 microns (Ref. 1). The depth filter did, however, remove a large portion of Niobium-95 from the waste stream. Any reductions in activity was considered a bonus to the process since the purpose of this apparatus was to remove solids. The total throughput of the filter prior to exhaustion due to pressure drop was approximately 1.5 million gallons, or 25,000 gallons per cubic foot of carbon media.

The final filter prior to ion exchange was a model 523A. During initial testing the 523A was utilized between the pre-filter and the depth filter. This resulted in influent solids of 200-400 ppm and effluent of less than 100 ppm. Subjected to these conditions, the filter was depleted after 7,000-8,000 gallons throughput. With the process logic revised to place the 523A downstream of the depth filter, throughput has improved to approximately 40,000 gallons.

The same analysis can be made on the 523A filters that are to be in place down-stream of the depth filter. Since the typical effluent is less than 100 PPM, 75 PPM will be used to calculate filter life for the dual 523A filters. At 20 GPM, 358 grams of dirt holding capacity, one filter would have a service life of 75,000 gallons or one and a half weeks. At 10 GPM and 465 grams each, two filters would not require changeout for about 95,000 gallons or almost two weeks. The expected throughputs at various flow rates for the 523A bags are shown on Figs. 3 and 4.

The changeout frequency may vary if filter dose rates increase to an administrative limit which has yet to be set. Typically, the filter bags are 500-700 mR on contact at changeout and result in a total exposure of 5-10 mR per change.

Ion Exchange Performance Benefits

Two additional goals of this testing were to increase throughput of each ion exchange bed by 100% and to meet the system effluent requirements as shown in Table II.

During operation with the previous system, the average throughput on a mixed bed ion exchange loading was approximately 140,000 gallons or 3,500 gallons/ft^3 of

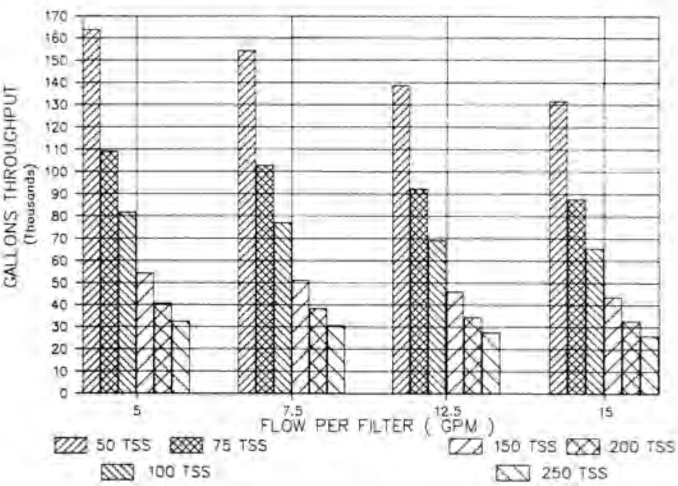

Fig. 3. Catawba Nuclear Station 523A Throughput vs. Flow Rate.

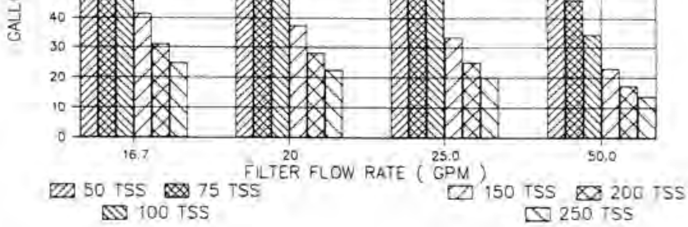

Fig. 4. Catawba Nuclear Station 523A Throughput vs. Flow Rate.

TABLE II
Test Goals and Results

Isotope	Average Feed (microCi/ML)	Effluent Goal (microCi/ML)	Average Effluent (microCi/ml)	Administrative Guideline (micro Ci/ml)	DF
Co-58	5.0 E-3	5E-5	2.4E-5	5E-4	202
Co-60	2.3 E-4	5E-6	4.3E-6	1E-5	54
Nb-95	4.6 E-5	1E-6	3.1E-7	1E-6	149
CS-134	4.7 E-5	---	2.7E-7	1E-6	170
CS-137	1.2 E-4	---	7.8E-7	1E-5	159
I-131	7.2 E-5	---	4.2E-7	1E-5	169

resin. During the portion of the filter test in which the refueling outage on Unit 2 was underway, the in-service demineralizer realized a throughput of 380,000 gallons (9,500 gal/ft^3) prior to exhaustion on Cobalt breakthrough, a 171% increase. After the outage, a throughput of 882,000 gallons (22,050 gal/ft^3 or 530%) was achieved. These throughputs were realized due to the entrainment of small particles in the filtration process, rather than on the ion exchange resin.

The next goal, which dealt with the improved quality of effluent from the entire processing system, was only marginally achieved. As shown by Figs. 5, 6 and 7, the effluent concentration of each isotope did exceed the test goal on a number of occasions although the averages did not.

The removal of the Niobium-95 was successful with only a few peaks above the goal (1.0E-6 microCi/ml). A contributing factor to the Niobium removal was the ability of the depth filter and the 523A filter to remove the particulate component from the waste stream. The ion exchange system was effective in the removal of the ionic component. The average Niobium concentration in the feed (4.6/E-5 microCi/ml) and in the effluent (3.10E-7 microCi/ml) yields a decontamination factor (DF) of 149. The DF across the depth filter was 22 for Niobium-95.

During non-outage inputs, the Cobalt-58 effluent was maintained below the test goal (5E-5 microCi/ml). During the input of the outage related water, the presence

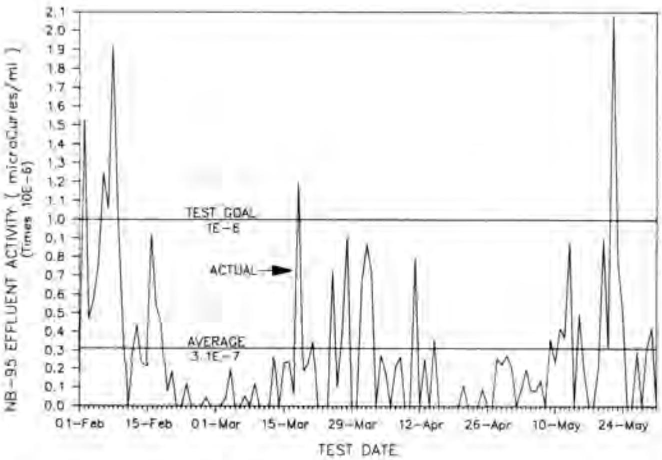

Fig. 5. Catawba Nuclear Station NB-95 Liquid Effluent During Testing.

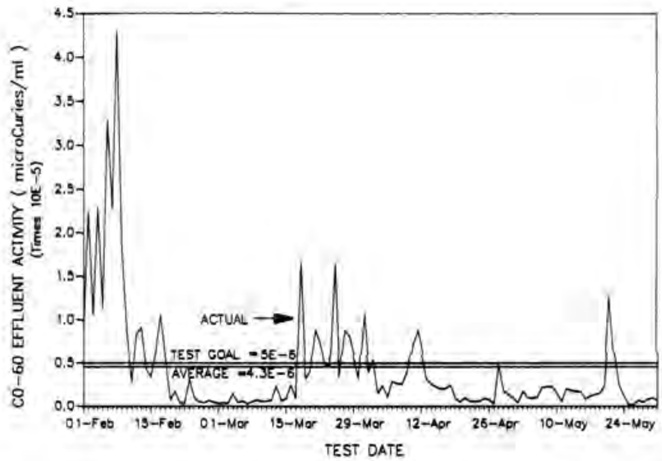

Fig. 6. Catawba Nuclear Station Co-60 Liquid Effluent During Testing.

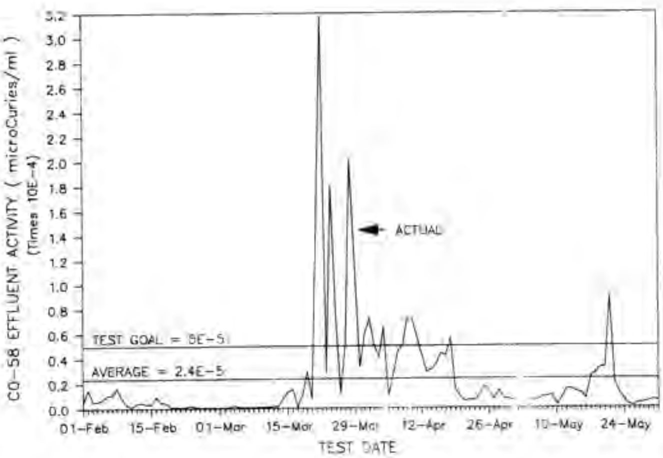

Fig. 7. Catawba Nuclear Station Cp-58 Liquid Effluent During Testing.

of increased colloidal Cobalt particles, higher solids concentration and higher conductivity caused the effluent quality to exceed the test goal. The inability to remove the colloidals indicate that none of the tested media would effectively filter below 0.2 microns, which as previously discussed is above the threshold for removal. The majority of the Cobalt-58 was removed by ion exchange. During the test, a new resin bed was placed in service downstream of the bed already in service. The effluent from that demineralizer was the same as that of the first bed. This reaffirmed the conclusion that the Cobalt-58 in the effluent of the first bed was due to non-ionic Cobalt species. The average Cobalt-58 DF across the entire processing system was 202. The DF across the depth filter was less than one, although this figure does not reflect the normal operating DF. During two separate periods, the pH of the feed stream dropped below 5.5. This resulted in the depth filter sluffing Cobalt that had been previously adsorbed by the carbon media. The effluent samples from these occurrences weighted the data such that the DF of less than one was attained.

Cobalt-60 behaved similarly to Cobalt-58 during the test. The same inability to remove the colloidal non-ionic portion resulted in occurrences in which the test goal (5E-6 microCi/ml) was exceeded. The average DF for Cobalt-60 across the system was 54. Across the depth filter, a DF of 1.4 was realized.

Cost Benefits

The final major goal was to reduce the operating and maintenance cost of filtration by 80%. Based on an average 400 ppm influent to the pre-filters, one and a half depth filter volumes and 75 ppm to the post filters, an estimated 91.8% can be saved over the 1987 and 1988 annual operating costs, as calculated in Ref. 2. Ion exchange costs based on an average of the outage and non-outage throughputs yields an 80% savings. The total costs savings exceed $360,000 or 86.5%. The tabulated figures are shown in Table III and Fig. 8. The figures for 1989 include two months of operation with the original filtration system.

The average per gallon processing costs for 1987, 1988 and 1989 are $0.155, $0.174 and $0.06, respectively. Based on a 2.1 million gallon annual processing volume, $0.027 will be spent per gallon on floor and equipment drain water processing in the future.

ION EXCHANGE OPTIMIZATION

With the filtration portion of the liquid waste processing system signifi-cantly improved, radionuclide removal via ion exchange was examined. The major species to be removed are Cobalt-58 and 60, Cesium-134 and 137, Niobium-95 and Iodine-131.

The system alignment at CNS will consist of three sluicible demineralizer skids, each consisting of two 30 ft^3 vessels, associated piping, instrumen-tation and shielding. Each of the three skids is loaded with a specific media to remove one or more of the above radionuclides.

Cation exchange beds at CNS are typically removed from service due to break-through on Cs-134 or Cs-137. In order to extend bed life and to enhance cesium

TABLE III
Projected Savings

	1987	1988	1989	Projected	Avg. Savings
FILTRATION	$317,441	$313,706	$ 77,654	$25,778	91.8%
ION EXCHANGE	$118,230	$ 95,680	$ 47,840	$30,900	71.1%
TOTAL PROCESSING	$435,661	$409,386	$125,494	$56,678	86.5%

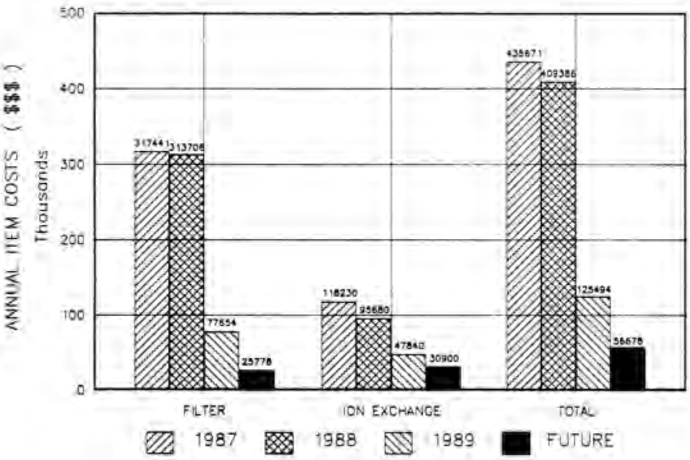

Fig. 8. Catawba Nuclear Station Radwaste Processing Costs.

removal, the first demineralizer vessel downstream of the filtration process will be loaded with a cesium specific clinoptilolite zeolite. Through-put and effluent quality in this application is still uncertain although bench scale testing has indicated that this media will readily and selectively remove a significant amount of cesium from the waste stream (Ref.1).

The second set of vessels will be loaded with a strong acid cation resin for the removal of ionic Cobalt-58 and 60, Niobium-95 that remains from filtration and any residual Cesium-134 and 137 from the zeolite bed. Through-put on these beds should be extended due to the upstream zeolite bed.

The final skid will be loaded with a strong base anion resin which easily removes the Iodine nuclides.

FILTER AND ION EXCHANGE MEDIA DISPOSAL

The introduction of these new medias requires advance preparation for their disposal. The disposal of the spent bag filters required further tests to verify the absence of free standing water (< 1% by volume) in the conical bottom High Integrity Container (HIC) used for disposal. Ten bags were expended on raw lake water and subjected to a blowdown pressure of 10 psig for a period of at least 10 minutes to remove as much water as possible. These depleted bags were compacted with a 9 ton compactor and all water collected. The average volume collected per bag was 128 milliliters. With a 95.8 cubic foot HIC and one average expended bag filter volume of 0.67 cubic feet, 4.8 gallons (.7%) of free water would be stored in the HIC. For conservatism, 150 bags, with an additional 50 mls. each, yielded 7.1 gallons or approximately 1%. Added conservatism includes much less than 9 tons of compaction, multiple dewatering cycles on the HIC prior to shipping and the evaporation or drying of moisture from the bags in the HIC prior to shipping preparation. With this conservatism, Duke Power has taken the position that bag filter disposal will not present a disposal problem.

The other three medias (bead resin, zeolite and carbon) can possibly be combined and disposed of in a separate HIC. Preliminary conversations with disposal site personnel have revealed that bead resin and zeolites may be disposed of together providing the mixture is homogeneous. The presence of a spare ion exchange vessel on each demineralizer skid will allow the scheduling of bead resin and zeolite bed sluices simultaneously through common piping to achieve the required uniform mixture. Procedures are currently in place to allow the disposal of carbon media with bead resin in the same disposal container.

SUMMARY

As a result of defining the waste stream particle distribution and extensive full scale testing, the final liquid radwaste process configuration at Catawba Nuclear Station consists of: four 527A (9 micron) bag filters, carbon depth filter, two 523A (1.5 micron) bag filters, three 30 cubic foot ion exchange vessels loaded with clinoptilolite zeolite, cation resin and anion resin, respectively and a post 525A (3.5 micron) filter for any resin fines. This lineup is also shown on Fig. 9. With the vastly improved filtration, CNS has and will continue to realize excellent performance by its ion exchange media. The previously stated effluent qualities should improve with the use of the cesium specific zeolite which will also allow for greater nuclide loading on the cation resin.

These changes allow CNS to progress further in a more efficient and cost effective approach to the processing of its liquid radioactive waste.

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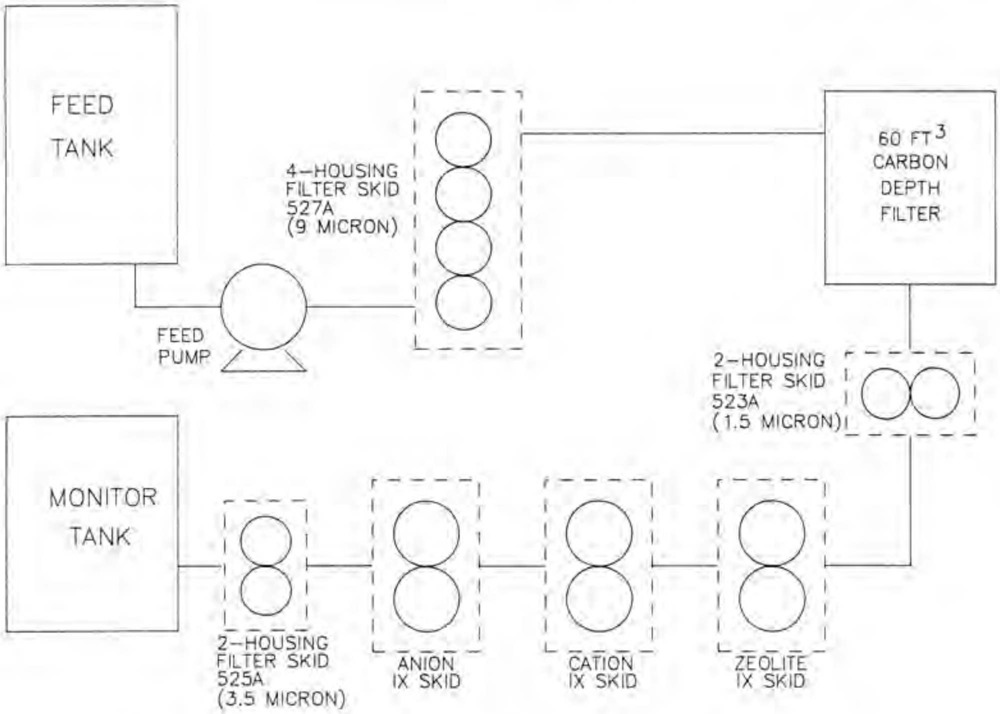

Fig. 9. Catawba Nuclear Station Liquid Radwaste Process System.