ADVANCEMENTS IN WASTE VOLUME REDUCTION USING NON-METAL AND DISSOLVABLE FILTERS

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ABSTRACT

Volume reduction offers the opportunity to save thousands of dollars in disposal volume costs. Recent developments have been made investigating two types of filter volume reduction technologies: non-metal filter reduction using pyrolysis, and dissolvable filters.

The first method uses Tank Conversion Reforming (pyrolysis) to volume reduce non-metal filters. This paper demonstrates the reduction of non-radioactive filters, and discusses the results obtained for nuclear applications where filters were volume reduced and disposed. Initial results indicate a volume reduction of approximately 90%. If void space reduction is included in the calculation, a net disposal volume reduction of 97% is attainable.

Dissolvable filter media is another potential method for volume reduction. The filter material is composed of polyvinyl alcohol, which can be dissolved in a device similar to an autoclave. The dissolved filter waste is a liquid, and liquid disposal methods were investigated. Ion exchange removal was ineffective, probably because of organic fouling; however, shipping the dissolved liquid with waste ion exchange resin for pyrolysis volume reduction proved to be a convenient disposal method.

INTRODUCTION

At the current time, high activity filter cartridges represent the most expensive routinely generated low level radioactive waste stream to dispose. This is primarily because of the poor packaging efficiency of filter cartridges with metal support structures. The majority of stations package medium-to-high activity filters in poly waste containers for direct disposal, resulting in a packaging efficiency that typically leaves > 66% void space in the container.

Recent advances in filter technologies suggest that many metal filters can be replaced with non-metal filter alternatives or a combination of non-metal filters and metal filter adapters (sleeves).

Two types of non-metal filters are evaluated in this paper; filters designed by Framatome ANP that may be volume reduced using Tank Conversion Reforming (TCR) process developed by Studsvik, and filters composed of a dissolvable polyvinyl alcohol material developed by OREX Technologies, which can be either dissolved or volume reduced by Tank Conversion Reforming. The Framatome filters (referred to as non-metal filters) are commercially available; the OREX filters (referred to as dissolvable filters) are still in development. EPRI does not endorse either product; these tests were evaluations of the concept of filter volume reduction.

A critical component of any study involving alternative filters is an assessment of the impact on plant systems. Essentially, this is a determination of:

(1) whether the alternative filters meet or exceed the specification requirements established for existing filters;

(2) whether system modifications are required;

(3) what type of modifications are required; and

(4) whether any required modifications would be cost prohibitive.

NON-METAL FILTERS

Three Mile Island (TMI), Perry Nuclear Power Plant (PNPP), San Onofre Nuclear Generation Station (SONGS) and Framatome-ANP collaborated with EPRI in two related studies. Framatome-ANP performed a technical review of the filters currently being used by TMI, and segregated the non-metal alternative filters into three categories:

1. Equivalency determination required – Some non-metal alternative filters are expected to serve as direct replacements for metal filters. The filters in this category do not require stainless steel sleeves or cores, and Framatome believes they meet or exceed all of the existing filter specifications, including having the same form, fit, function, flow, micron size, and physical dimensions as existing plant filters. However, neither Framatome nor EPRI is in a position to make a final determination that any given filter will meet the service requirements for any plant-specific filter housing. This "equivalency determination" should be performed by plant Procurement Engineers or the System Engineer. In some rare cases, it may be necessary to obtain the advice or assistance of the system supplier (e.g., B&W, CE, GE, Westinghouse).

2. Non-mechanical modification (minor mod) required – Because of high system temperatures and pressures, some alternative non-metal filters will require stainless steel sleeves with a stainless steel core to be inserted into the filter housings to ensure structural support. The "non-mechanical modification" category consists of those non-metal filters which require metal sleeves and which do not require any mechanical changes to the filter housing. The sleeve is a press fit; no drilling, grinding or other mechanical modifications are required to insert and hold the sleeve in place. However, it is anticipated that the inclusion of metal sleeves will require at least an engineering technical and 10CFR50.59 safety review and may also require changes to plant drawings.

3. Mechanical modification (major mod) required – It is anticipated that this category of filter will require a mechanical modification to the filter housing, as well as a comprehensive engineering review and drawing changes. Mechanical modifications may include drilling (e.g., bolt holes), grinding, or even a change in filter housings. This category could apply regardless of whether the alternative non-metal filter requires a stainless steel sleeve.

Note: Filters in contact with the primary coolant may require communication (and approval) of not only systems engineering, but also the chemistry and nuclear fuel groups. The industry is currently using primary filtration with filtration thresholds as low as 0.1 microns to help remove particulate and colloidal activity. The filter vendor should be consulted to determine if the non-metal filters can meet these specifications.

TMI assessed which filters may be replaceable, and a summary of the results is below in Table . For more detail, refer to References [1] and [2].

Table I. Summary of TMI filters that are candidates for non-metal filter cartridges

Description	*Filter Size (μm)*	*Waste Class*
Letdown Filter A	1.00	A
Letdown Filter B	3.00	A
Letdown Pre-filter A	0.45	BC
Letdown Pre-filter B	3.00	BC
Reactor Cavity Cleanup Filters (Tri-nuke)	1.00	A
Reactor Cavity Cleanup Filters (Tri-nuke)	0.30	A
Reactor Cavity Cleanup Filters (Tri-nuke)	0.50	A
Cation Demin A Resin Trap	10.00	BC
Cation Demin B Resin Trap	10.00	BC
Evaporator Condensate Demin Resin Trap	50.00	A

Stainless Steel Adapters and Disposable Media Filters

Framatome-ANP developed and patented the concept of "disposable media filters" or DMF employing reusable stainless steel shrouds and, when necessary, stainless steel cores. Current designs exist for the majority of nuclear plant filter applications. The DMF is a two-part system consisting of a disposable media cartridge and a stainless steel adapter. These are illustrated in Fig. 1. The photo at the left shows the both the cartridge and the stainless steel adapter. The photo at the right is a top view of the adapter, which shows how the cartridge would fit between the stainless steel outer shroud and inner core structures.

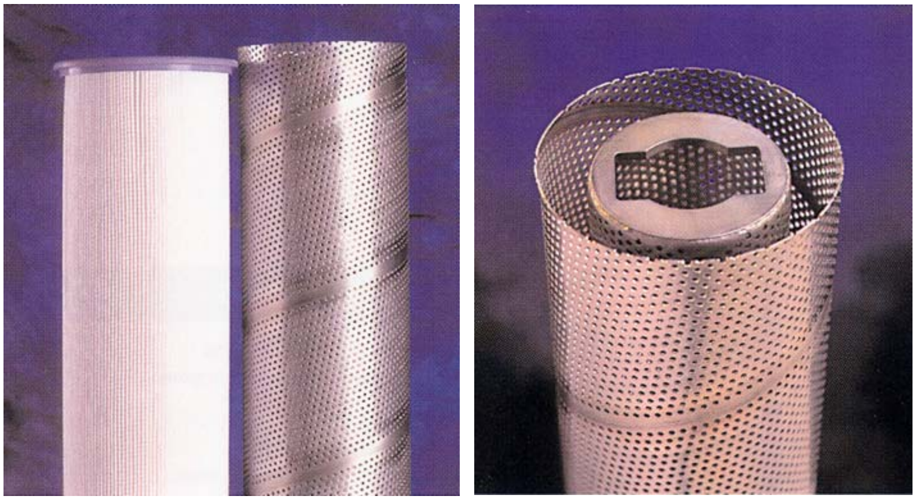

Fig. 1 Disposable Media Filter Cartridge and Stainless Steel Support Shell.

The DMF stainless steel adapter provides the necessary structural interface between the filter cartridge and the plant filter vessel, which is essential in high pressure, high temperature systems. In so doing, the adapter becomes a semi-permanent part of the filter vessel, absorbing the dynamic filtration loads and providing the strength necessary for the filter to maintain structural integrity. The DMF adapter provides service up to 75 psid (5 bar) at 250°F (121°C) for polypropylene and polysulfone filter media, and up to 230°F (110°C) for glass fiber media. Note: Fiberglass filter cartridges cannot be loaded in the tank conversion reformer. However, most filters contain only incidental glass fibers, which are acceptable for reforming.

Tri Nuclear Corporation Filter Replacements

Tri Nuclear Corporation filter systems are used in most US nuclear plants, primarily during outages for filtration of reactor cavity water and BWR dryer separator pools. Tri Nuclear filter housings use from one to four filters, depending on the desired flow rate. For example, a 200 gpm system might require only one cartridge filter, whereas a 600 gpm system might require four cartridge filters. These filters typically represent a significant percentage of the industry's generated high activity metal filters and therefore represent an important target for non-metal filter applications.

The non-metal alternative filter proposed by Framatome for application at TMI in Tri Nuclear filter housings does not require a filter adapter. There is a potential for filter media failure and discharge into the primary system (e.g., the reactor cavity is connected directly to the reactor coolant system during refueling). It is a valid engineering concern; however, the Tri Nuclear system is a suction (vacuum) system. The suction system helps mitigate the potential for a blow-out and the need for metal shrouds or cores; however, a thorough test program should be planned to ensure the filter meets engineering requirements.

Note: The non-metal alternative filter offered by Framatome for use in Tri Nuclear filter systems has three times the surface area as the standard metal Tri Nuclear filters. This greater surface area offers the potential for longer filter life when used during long outages or for other extended filtration applications. It also has the potential for accumulating higher total activity, resulting in higher dose rate filters and potentially a higher waste classification. Plants should not automatically assume that these filters or housings will have the same dose rates as experienced in previous outages. A waste classification, transport, VR, disposal, filter handling ALARA review is recommended prior to initial replacement.

Non-Metal Filter Volume Reduction

As discussed earlier, Perry Nuclear Power Plant (PNPP) and San Onofre Nuclear Generating Stations (SONGS) are participants in this study. PNPP arranged to make its reformed filter waste information available for 2003 and 2004; SONGS will be providing its waste data for filter cartridges reformed in 2005. Other 2004 data were obtained from Studsvik for unspecified plants (plants not participating in this study) and for shipments containing only non-metal filter cartridges. These data were combined with the PNPP data to produce Table , which is used to assess economic implications of tank conversion reforming.

Table II. Observed volume reduction benefits for non-metal filters

Client	Input Volume (M^3)	Output Volume (M^3)	Volume Reduction Ratio
Perry NPP 2003	1.95	0.19	10.1:1
Perry NPP 2003	1.95	0.19	10.1:1
Perry NPP 2004	2.01	0.29	6.8:1
Other 2004	2.54	0.38	6.8:1
Other 2004	2.54	0.31	8.2:1
Other 2004	2.54	0.17	15.2:1
Totals	**13.54**	**1.53**	**8.8:1**

The most significant value of the results from Table is that the results represent actual field data from nuclear plants. All of the filter cartridge waste in the table was generated within nuclear plant filter housings. In contrast, most of the waste evaluated in the original 2003 study was based on laboratory analyses and the filter cartridges from the dewatering laterals of waste liners and high integrity containers.

Results for Volume Reduction Efficiencies for Filter Conversion Reforming

As with incineration, conversion reforming reduces the weight (and mass) of the input waste substantially, which contributes to volume reduction. The volume reduction efficiency of the as-generated waste is dependent primarily upon the inorganic content of the waste (percent of fiberglass, sludge, etc.): the higher the inorganic fraction, the greater the final disposed waste volume, and the lower the net VR efficiency.

The Net Disposal VR can be determined using the following formula:

Net Disposal VR = TCR Waste VR x Void Space Reduction

where: **VR** = volume reduction
TCR Waste VR = volume reduction due solely to the tank conversion reformer
Void Space Reduction = void space in a collection container of spent filters

Determination of TCR Waste VR

The data from Table report a total input volume for nuclear plant non-metal cartridge filters of 13.54 M^3. Measurement of the reformed residue in the waste disposal HICs resulted in a total of 1.53 M^3. This results in the following calculated VR:

TCR Waste VR = 479.4 / 54.2 = **8.8:1** (= 89%)

The original laboratory study based on a mixture of clean filters with a wide variety of filter construction materials produced a TCR Waste VR of 14.56:1. The report questioned whether this VR ratio would apply to nuclear plant spent filter waste which contained sludge, salts, metal oxides, absorbent materials, etc. Accordingly, it was an objective of the current study to obtain results from conversion reforming of actual plant filters (i.e., field data), which is shown above to be 8.8:1. It is likely that, as more plants participate in the continuing study and more field data is obtained, the average ratio will again fluctuate, but this result is considered to be more representative of plant filter cartridge waste.

Determination of Void Space Reduction

Referring to EPRI report TR-1007863, *Waste Containers for Extended Storage, Rev. 1*, August 2003, there are two commercially available 8-120 liners and two commercially available 8-120 HICs. These are the most commonly—but not exclusively—used containers for the collection and transport of high activity filter cartridges. These four containers have an average external disposal volume of 124.03 ft^3 (3.51 M^3) and an average internal volume of 112.08 ft^3 (3.17 M^3). Industry experience indicates that the irregular shapes and sizes of filter cartridges results in only 20 to 32 ft^3 (0.57 to 0.91 M^3) of filter waste per 8-120 container. For the purpose of this analysis, it is assumed that 30 ft^3 (0.85 M^3) of filter cartridges are typically placed in an 8-120 container, with the following results:

Void Space Reduction = 112.08 / 30 = **3.74:1** (= 73%) (Eq. 1)

$Note_1$: The use of tank conversion reforming has no impact on the external container volume and only impacts the effective use of the internal volume and the net void space. That is why the above calculation relies on internal container volumes.

$Note_2$: An EL-142 is a larger and also commonly used collection container for filter cartridges. The same calculation applies, although plants using the EL-142 should use an external volume of 132.4 ft^3 and an internal volume of 113.6 ft^3.

The net waste volume should be adjusted based on actual plant data. For the purposes of this report, the above calculation is sufficient for use in all subsequent analyses.

Determination of Net Disposal VR

The above results are inserted into the equation for Net Disposal VR:

Net Disposal VR = TCR Waste VR x Void Space Reduction (Eq. 2)
= 8.8 x 3.74 **= <u>32.9:1</u>** (= 97%)

DISSOLVABLE FILTERS

As stated previously, Orex Technologies International (now named Eastern Technologies, Inc.) has developed a material that can be manufactured into traditional wound filter media configurations and converted from a solid to liquid state using a proprietary process. Under the direction of its steering committee, EPRI committed to evaluating the applicability, performance, cost efficiency, disposal volumes and options, and challenges related to use of this advanced material in radioactive liquid processing applications.

Experiment Description

Dominion’s Surry Station volunteered to host the pilot testing in their Surry Radwaste Facility (SRF). This facility houses LRW processing system tanks, pumps, filtration, ion exchange vessels, membrane technology, and a laboratory with a sample sink and instrumentation. Testing of the OTI filter media was performed on selected liquid radioactive waste streams at the site. A small filter housing was connected to the SRF’s sample system. Sample filters are shown in Fig. 2. Two separate tests were conducted, each using a new filter element and supplied by different source waste streams. The allowable endpoint activity concentrations (dose rate < 10 mR/hr) for the filters was primarily controlled as a function of the station’s ALARA practices and laboratory setting. Using a scaled version of the OTI process, the resultant spent filter media was converted into a treated polyvinyl alcohol (TPVA) solution.

Fig. 2. OREX Technology cord-wound filter.

The TPVA was processed using new ion exchange media to create a final waste form that was classified to verify its acceptability for disposal at the Barnwell and Envirocare disposal sites. The goal was to demonstrate that ion exchange media would provide activity reduction and that the TPVA solution would not degrade the media. This would demonstrate the potential for future use of partially depleted ion exchange resins (e.g., condensate, blowdown, LRW) in a shipping liner/HIC as an atmospheric filter/demineralizer to polish the solution, returning the decant liquid to plant radwaste systems. Alternatively, the spent media could be dewatered using current plant practices, then the TPVA solution would be added to the container. The ion exchange media and TPVA slurry would be processed off site using currently available pyrolosis technology. More details are available in Reference [3].

Filtration and Treatment Results

The media’s structural integrity was satisfactory with no obvious deformation or failure during the low pressure test. Test results would indicate that the activity removal efficiencies appear to be low; however this first phase of the project was not intended to measure particle removal efficiencies, but rather the overall media-to-process compatibility. The decontamination factors (DF) are captured in Fig. 3. The volume of liquid processed was small; therefore the DFs were not weighted by liquid volume, but were calculated solely as a function of influent and effluent activity.

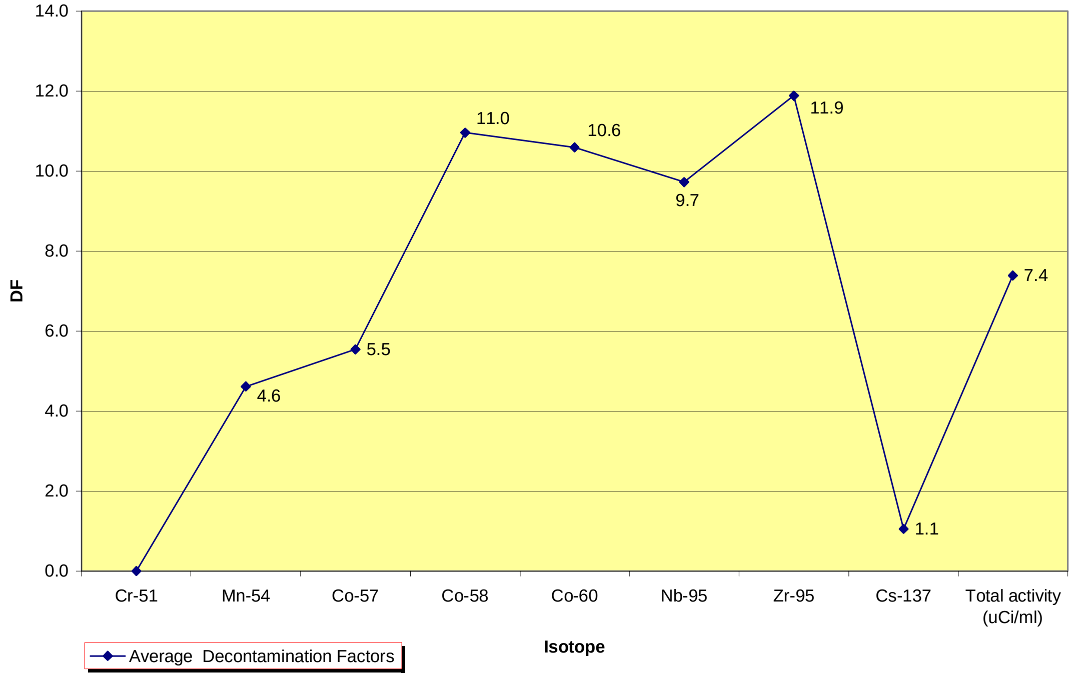

Fig. 3. Decontamination factors for various isotopes filtered through a cord-wound OREX filter.

The filter run-time was very short because the filter activity constraints imposed from personnel exposure concerns. It is expected that the media performance may have improved as it became more burdened with solids. The particulate removal capability was clearly demonstrated as relatively rapid increased in contact dose rates and significant visible darkening early in the filtration test. Additionally, the filter used was a prototype and was manufactured with a 1 micron nominal rating. Laboratory testing of a similar filter yielded performance results more consistent with a 5 micron filter. Based on that and the low activity influent liquid waste, the overall results for activity removal are considered to be satisfactory.

The solid filter was efficiently processed using the OTI proprietary treatment to a TPVA state. Obtaining a representative sample of the liquid for regulatory required waste classification analyses could be challenging because of particulate settling and temperature stratification. However, the laboratory setting used a magnetic stirrer as part of the scaled dissolution process to maintain solution homogeneity. However, for full scale operations, a solution to this design challenge will have to be incorporated into the processing equipment design.

Processing the TPVA solution through new ion exchange media did not produce the desired results. The DFs were very low and the full scale approach being evaluated that incorporated the use of partially depleted waste ion exchange media would only further reduce the viability of this option. Additionally, the use of partially depleted (radioactively burdened) media in the low pH regime associated with the TPVA solution would quite likely result in the media throwing activity back into the effluent stream that would be routed back to the plant waste collection systems. The second option of off site volume reduction of a plant spent resin and TPVA slurry using pyrolosis appears to provide the best overall disposition approach.

The ion exchange media was analyzed to be compatible for either volume reduction (preferred) or direct disposal. Four months after the test was completed, the waste resin was examined to determine its physical state. No visible negative effects (e.g., gelling, dissolution) were observed and its condition was found to be as left four months prior. This information is important for stations that would process the TPVA to a full spent resin liner and potentially hold that liner on site until a shipment for off-site VR could be arranged.

CONCLUSION

Non-metal filters are a viable alternative for many filters in PWR plants. The filters are in many cases technically and financially practical; however, each station will need to develop an equivalency protocol to determine if the filter will satisfy the process requirements. Actual plant data have shown 89% volume reduction, with some applications having volume reduction ratios as high as 15:1. When void space reduction is considered, the net disposal volume reduction may be as low as 97%. Non-metal filter evaluation is recommended for all stations. Their use is recommended where they are economically and technically feasible, and where volume reduction is needed to meet low-level waste disposal goals.

Dissolvable filters have demonstrated practical application and should be investigated further; however, they are not yet commercially viable. The solid volume reduction is almost 100%; however, characterization, treatment, and disposal of the liquid waste remain engineering challenges.

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