DEVELOPMENTS IN BACKWASHABLE FINE FILTER

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ABSTRACT

Defueling operations of the TMI-2 reactor require water clarity of 1 NTU to enable the operators to manipulate components located under 40 feet of water. Filtering systems presently available were evaluated to meet the requirements of defueling operations and found unacceptable. Hence, a novel filtration scheme has been developed and tested in the laboratory. Results of laboratory tests and the status of pilot tests simulating the conditions in the TMI-2 reactor are discussed.

INTRODUCTION AND BACKGROUND

Because of the damage done to the TMI-2 reactor core, the potential for high radioactivity concentrations and high turbidity levels within the reactor vessel is high, as evidenced by earlier studies. Therefore, during disassembly and defueling of the TMI-2 reactor, it will be necessary to fill the refueling canal with borated water above the reactor vessel to provide a radiation shield for the workers on the fuel handling bridge.

In addition to the fines (approximately 30,000 lb less than 40 μm size) that already exist in the damaged reactor core, it is anticipated that fines will be generated because of cutting operations during disassembly of fused and deformed components in the core. Suspended fine particles (<40 μm) will contribute to high turbidity. In order to maintain water clarity of 1 NTU, the reactor vessel water will have to be filtered continuously.

The filtration equipment that will be used to capture fuel fines in the range of 0.5 μm to 800 μm (based on sample analysis and estimate) will have to meet the critically safe conditions that are essential for the defueling operations. Moreover, the process equipment has to be adequately shielded and must be capable of remote operation to reduce the man-rem exposure. The filtered solids will have to be stored and shipped in a fuel canister.

CRITERIA

To meet these constraints and process requirements, the following criteria have been developed for the selection of a fine filter:

- The filter medium shall be capable of filtering 0.5 μm (nominal) particles.
- The filter medium shall be backwashable, and the recovery pressure drop after the backwashing cycles shall stabilize within the operating limits (20 to 30 psid) of the filter.
- The filter configuration should yield itself to the criticality-safe conditions.
- The filter system shall have minimal interfaces, so as to minimize the complexity and increase the reliability of operation.
- The filter system shall be reliable, flexible, and require minimal maintenance.
- The filter configuration shall be such that it can be adequately shielded in the refueling canal water and the system operated remotely at a minimum capital and operating cost.

EQUIPMENT SELECTION

The following filter equipment has been considered in evaluating the alternate schemes:

- o Etched disc filters
- o Sintered metal filters
- o Ultrafiltration

Etched Disc Filters

Etched disc filters have been used in the nuclear power industry to filter waste liquid streams containing low concentrations of solids. Etched disc filters with absolute size ratings of 5 μm have been used in nuclear applications.

Advantages	Disadvantages
o Operating experience with radioactive waste	o Not proven/used to filter 0.5 μm particles
	o Low solids holding capacity before backwashing (<0.1 lb solid/sq ft of filter area)
	o High-pressure (300 psi) air source required for back bump
	o Requires frequent back bump

Sintered Metal Filters

Backwashable sintered metal has also been used in the nuclear industry at the Savanah River fuel reprocessing plant with a 2 μm size filter medium. These filters require only about 100 psi for backwashing.

Advantages	Disadvantages
o Operating experience in the nuclear industry	o Not proven with 0.5 μm filter medium
o High solids loading (0.2 lb solids/sq ft of filter area)	
o Compatible with fuel canister design	

Ultrafiltration

Ultrafiltration uses an organic polymer membrane to filter the soluble salts and solids. Even though it has been used in nonnuclear applications, this filtration is new to the nuclear industry. The effects of its extended exposure to radioactive material and the final disposal of the organic membrane along with the fuel fines have yet to be investigated for this application. The solids loading for this type of filter is below 0.05 lb solids/sq ft of filter area. Therefore, this filter has not been considered further.

FILTER CONCEPT

The etched disc and sintered metal filters can be considered for this application because of nuclear operating experience. However, etched disc filters or sintered metal filters cannot be used in the readily available configuration without further criticality analysis and system interface checks. In light of these constraints, a filter concept has been envisioned that incorporates the filter medium into a fuel canister in such a way that there is no interface between the filter medium and the fuel fines holding section.

Fuel canisters are presently being designed to handle the damaged fuel in the TMI-2 reactor. The objective of the present design is to ensure the critically safe conditions at all times (loading, transporting, and storing) by having proper canister dimensions as well as incorporating poison material into the canister if needed. A fuel canister 13.25 inches in outside diameter by approximately 14 feet high is being considered, since these dimensions are suitable for loading fuel rod assemblies and since it is intended to have only one canister design for all fuel rods and fuel debris.

The etched disc filter element was considered and rejected, based on: a) nonavailability of 0.5 μm size filter medium; b) difficulty in adapting etched discs to the filter canister; and c) the high pressure backwash requirement of 300 psi, which is higher than the design pressure of the fuel canister (150 psi). Therefore the following filter concept has been developed that incorporates a 0.5 μm sintered metal filter medium into the fuel canister without extensive modifications.

The filter concept is depicted in Figure 1. The unique feature of the proposed system is that the solids will not be removed from the filter housing during back bump. Instead, the solids will be allowed to settle and concentrate in the bottom of the canister, below the porous medium. The dirty fluid stream enters the fuel canister from the tube side, and the clean fluid exits through the filter medium (inside of the tube to outside) to the shell side. During back-bump operation, the filter outlet valve will be closed and the back-bump air valve will be opened. During this operation, the filter cake collected inside the tube during normal operation will be dislodged. The dislodged solids will settle to the bottom of the filter canister.

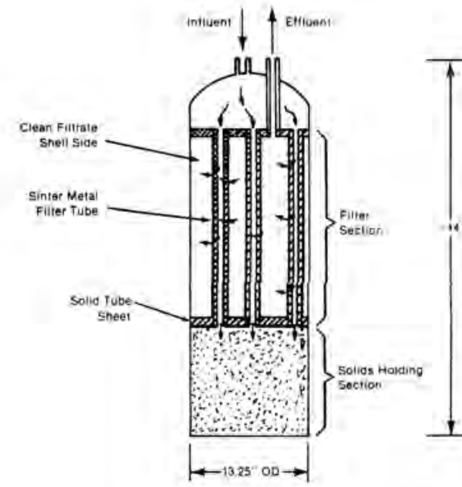


Figure 1.
FILTER CANISTER CONCEPT

In order to evaluate this filter concept, a laboratory scale filter test has been done with the cooperation of Mott Metallurgical Corporation.

LABORATORY SCALE TEST

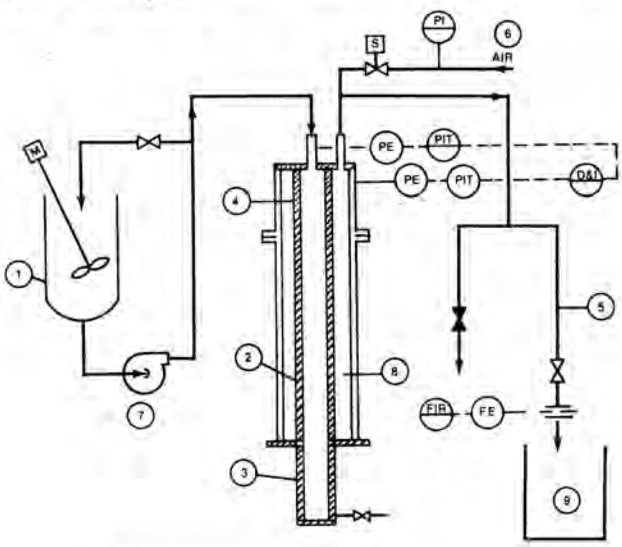
Objectives

The objectives of the test were to determine:

1. The quality of the effluent from the Mott's 0.5 μm sintered metal porous medium.
2. If the solids could be bumped off the medium.
3. If the solids could settle to the lower housing area by gravity.
4. The effect of cycles on the recovery pressure drop of the filter medium.

Test Equipment

The filter housing consisted of 1.5 in. Schedule 40 pipe (1.6 in. inside diameter). The element was a standard Mott 0.5 μm 316SS seamless tube, 0.75 in. outside by 0.625 in. inside diameter (bubble point: 4.1 in. Hg). The active porous area was determined to be 0.643 sq ft. The filter system hardware is depicted in Figure 2.



1. Mix holdup tank for slurry batch (30 gal)
2. Sintered metal filter tube 3/4" OD, 5/8" ID x 4' long (0.64 ft² filter area)
3. Back wash slurry hold tank 2" ⌀ x 2" length
4. Inlet tube
5. Filtrate outlet
6. Air inlet for back wash (100 psi)
7. Slurry feed pump (0.1 – 1 gpm variable speed pump)
8. Filtrate shell
9. Filtrate holdup tank

Figure 2.

EXPERIMENTAL TEST UNIT

Test Solution and Solids

Test Solution:

Testing was performed using a borated water solution as the initial clean liquid to give roughly 3,500 ppm borated water at a pH of 7.8.

Solids:

a. Zirconium oxide from Tam Ceramics "Zirox 70"

Particle size distribution:	100% <5.0 μm
	60% <1.0 μm
	10% <0.5 μm

b. Iron oxide from Pfizer

Red iron oxide (RO-30)	Yellow iron oxide (YO-20)
98% <2.0 μm	100% <5.0 μm
90% <0.6 μm	65% <0.4 μm
45% <0.2 μm	20% <0.2 μm

Testing

Twenty cycles were performed at a constant flow rate of 0.5 gpm/sq ft (except for the last three cycles) at different solids concentration. Feed flow continued until a differential pressure of 40 psid was attained. At that pressure drop, the feed flow was stopped, and the upper dome pressure was evacuated. This was done to create a compressible gas pocket for back bump. After the bypass operation, compressed air at 100 psi was introduced into the clean side of the filter for 0.5 second. The solids were then allowed to settle for 2 to 5 minutes. Forward flow was then reintroduced, and the next cycle was performed. Turbidity samples were taken every minute.

Cycle Conditions

1 through 5:	6,614 ppm ZrO_2
6 through 15:	6,614 ppm ZrO_2, 695 ppm Fe_2O_3 (red), and 543 ppm Fe_2O_3 (yellow)
16 and 17:	1,322 ppm ZrO_2, 139 ppm Fe_2O_3 (red), and 109 ppm Fe_2O_3 (yellow)
18, 19, and 20:	1,322 ppm ZrO_2, 139 ppm Fe_2O_3 (red), and 109 ppm Fe_2O_3 (yellow) at 0.75 gpm/sq ft flow rate

RESULTS AND DISCUSSION

The results of the tests were categorized in three ways: a) filtrate turbidity, b) solids holding capacity per cycle, and c) recovery differential pressure.

Filtrate Turbidity

During cycles 1 through 5, turbidity seemed unusually high, as shown in Figure 3. After five cycles, the filtrate turbidity was in a steady decline. This is due to the fact that the filter element became conditioned after a few cycles. It was also observed that a high turbidity condition occurred immediately following a back bump. The turbidity improved as the surface cake was reconstructed. High turbidity values in cycles 11 and 16 are due to the solids being drained out of the system.

Solids Holding Capacity

Solids holding capacity was determined by performing the solids material balances for each cycle. The amount of solids deposited in each cycle was relatively steady (between 60 and 100 gm/sq ft) until cycle 13, when it dropped below 50 gm/sq ft. Cycle 14 showed little improvement. This may be due to the fact that the system was drained after cycle 11. The two most significant factors affecting the solids holding capacity will be settling time and the settling volume below the filter elements.

Recovery Differential Pressure

Recovery differential pressure is an important parameter, since it reveals whether the solids have penetrated through the filter medium during the filtration cycle, thus causing the blinding of the filter elements. The common pressure rise associated with the element conditioning was evident in cycles 1 to 5. Beginning with cycle 6, the recovery pressure stabilized between 10 and 14 psid. Through 20 cycles, there was no indication of element degradation.

CONCLUSIONS AND RECOMMENDATIONS

The tests indicate that acceptable filtrate turbidity can be produced at an acceptable and repeatable recovery pressure. Secondly, the solids can be removed from the porous wall with a back bump. Therefore the use of a sintered metal filter in the defueling operation is a viable and promising option.

In order to confirm the use of the sintered metal filter medium in the fuel canister, it is recommended that a prototype filter unit be tested using a simulated (i.e., dimensionally approximate) fuel/filter canister, operating under simulated water quality conditions (UO_2 and ZrO_2 fines in borated water), to evaluate the flow distribution characteristics inside the filter and to establish filter performance. Potential problems, such as bridging of the filter tube sheet, could be identified during the test for subsequent resolution. Hence, additional testing on a more representative basis is being planned at Babcock & Wilcox facilities.

Acknowledgement: The authors appreciate Mott Metallurgical Corporation's valuable cooperation in performing the filter tests.

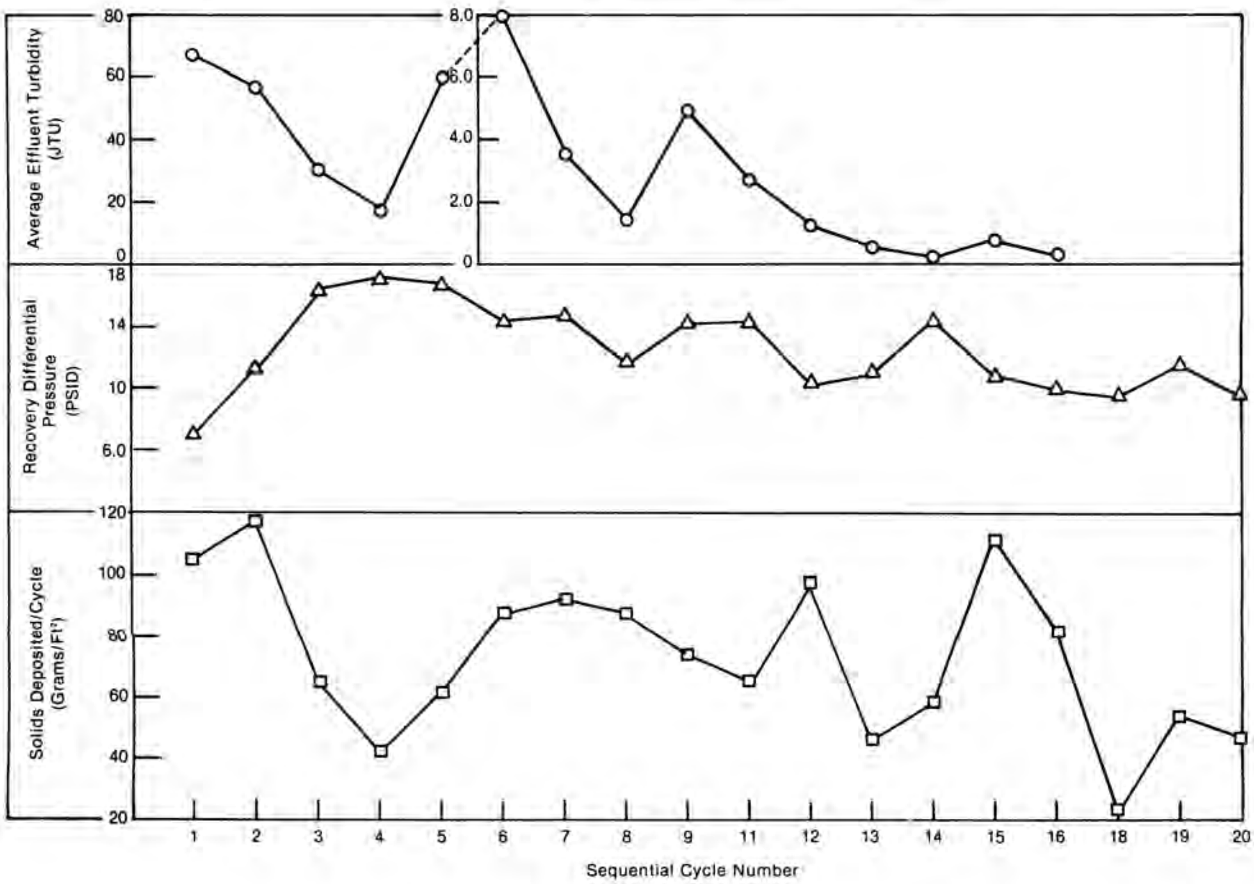


Figure 3.

EFFECT OF BACK WASH CYCLES ON FILTER PERFORMANCE