TMI-2 DEFUELING FILTER DEVELOPMENT TESTS

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ABSTRACT

An important aspect of the Three Mile Island Unit-2 (TMI-2) Recovery Operation is the water treatment techniques used to maintain water clarity and control radiation levels during the operation. It has been determined that a water clarity ≤ 1.0 Nephelometric Turbidity Unit (NTU) is required to meet these two objectives. Conventional filtration systems do not meet all of the criteria constraints unique to the defueling operation. Two novel sintered stainless steel media filter concepts were identified and investigated. The test results of the pilot plant program conducted at Babcock & Wilcox's Lynchburg Research Center leading to the development of a Filter Canister are presented.

INTRODUCTION

The Three Mile Island Unit-2 Reactor (TMI-2) Recovery Operation presents a significant challenge to the nuclear industry. An important aspect in the TMI-2 Recovery effort is the water treatment techniques used to maintain water clarity and control radiation levels during the defueling operation.

The defueling operation at TMI-2 requires that high water quality be maintained. In an undamaged reactor suspended corrosion products can cause a visibility problem. The TMI-2 reactor sustained damage creating a significant quantity of fine debris which can become suspended when disturbed during the defueling activities. It is necessary to ensure adequate water quality for direct viewing of the defueling operations and to provide that radiation dose rates to workers from suspended solids are as low as reasonably achievable (ALARA).

It has been determined that these two objectives can be maintained if the turbidity of the borated water is ≤ 1 NTU. The Defueling Water Cleanup System (DWCS) has been designed by GPU Nuclear Design Engineering (DE) to achieve these objectives. A primary component in the DWCS is the Filter Canister.

Babcock & Wilcox (B&W) under contract to GPU Nuclear Corporation has developed a containerization system consisting of three canisters. One of these canisters is the Filter Canister. The Filter Canister is a component in both the DWCS and the Fines/Debris Vacuum System (F/DVS). The Filter Canister is designed to remove suspended debris particles from reactor coolant water. Externally, the filter is similar to other canister types. These are described in detail in another B&W paper[1]

There are several filter performance criteria important to B&W's effort in the development of a filter canister. These are as follows:

1. The filter should be capable of removing fine debris sized above 0.5 micron to a maximum particle size of 800 microns.

2. The effluent turbidity from the filter should be equal to or less than 1.0 NTU.

3. The Filter Canister's operating life should be sufficiently long to allow the canister to accumulate 400 pounds of debris.

4. The Filter Canister should have a minimum flow capacity of 100 gallons per minute.

5. The chemical nature of the borated water should not be altered by the filtering process.

6. The Filter Canister configuration should provide a critically safe geometry for a 30-year storage period.

7. The overall filtration system should have a straightforward operational format that minimizes complexity and promotes system reliability.

BACKGROUND

Based on both the Quick Look inspection and core debris sample analysis, it has been determined that the TMI-2 reactor contains significant quantities of debris fines. It is estimated that a large portion of core debris has a particle size of 40 microns or less. In addition, other fines are expected to be generated as a result of the defueling operation.

The suspended debris fines < 40 microns contribute to the anticipated high turbidity in the reactor core. To reduce the turbidity a filtration system capable of maintaining the water clarity at 1 NTU is required.

Early in 1983, GPUN considered a variety of filtration systems. Alternates reviewed included etched disc filters, sintered metal filters, and ultrafiltration. The evaluation precluded the use of organic polymer-based filters because of the extended radiation exposure that the filter canister would receive. The early filter studies were reported in a paper presented at the Waste Management '84 Conference.[2] As a result of that work, GPUN identified a backwashable tubular porous 0.5-micron sintered stainless steel filter concept for the TMI-2 water treatment system.

The filter offered the potential of a relatively high flow rate in a self-contained unit. By being backwashable, the solids removal capacity of the filter could be expected to be high. In addition, a nominal rating of 0.5 micron suggested the filter could effectively remove a high percentage of the submicron particles expected in the reactor coolant.

Two filter vendors who manufactured a 0.5-micron porous sintered 316L stainless steel filter media were Mott Metallurgical Corporation and the Pall Trinity Corporation. Preliminary filter feasibility tests were conducted by both vendors.

As a result of the preliminary vendor tests, GPUN decided to pursue the Mott filter concept. Proof-of-principle testing of the Mott filter was initiated by B&W. During the Mott filter testing program the Pall Trinity Corporation provided a different sintered stainless steel filter concept. The new Pall concept offered the potential of significant advantages over the tubular filter element, and it was incorporated into B&W's filter test program.

FILTER CONCEPTS

Mott Metallurgical Filter Concept

The Mott filter concept is based on a porous sintered 316L stainless steel tubular filter element (0.75-inch OD/0.625-inch ID/6-foot length). Solids are loaded on the inside diameter of the filter at a constant flowrate until a predetermined differential pressure across the filter is reached. The system then automatically shuts down and the filter is hydraulically backpulsed to remove the collected solids. After allowing the solids to settle into a plenum area, the filter operation is restarted. The filter is operated in a cyclic mode until the plenum is loaded with solids.

A conceptual Mott filter canister is depicted in Fig. 1. B&W conducted extensive testing of a single Mott filter element. Proof-of-principle testing was demonstrated at this scale. Further full-scale testing of the Mott concept was suspended when the Pall filter concept was identified. Reasons for adopting the Pall Filter Concept include:

1. Elimination of backwashing.

2. Continuous filtration operation versus cyclic operation.

3. Elimination of a complex filter control system.

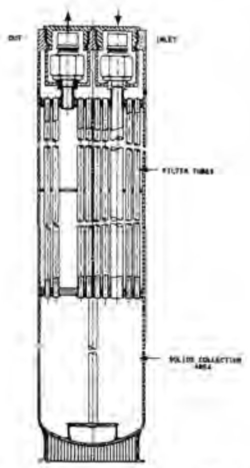

Fig. 1. Mott Filter Canister.

Pall Filter Concept

The Pall Trinity Micro Corporation produced a new filter media which is a combination of woven stainless steel wire mesh with stainless steel powder sinter bonded to its process stream surface. The media is approximately 0.016 inch thick and can be fabricated into a pleated cartridge type module.

The cylindrical filter cartridges are 11 inches long with a 2.5-inch OD (Fig. 2). In operation, the filter cartridge is loaded with solids on the OD surface at a constant flowrate until a differential pressure of 40 psid is reached. At 40 psid the filter cartridge will have collected sufficient solids to consider the canister fully loaded.

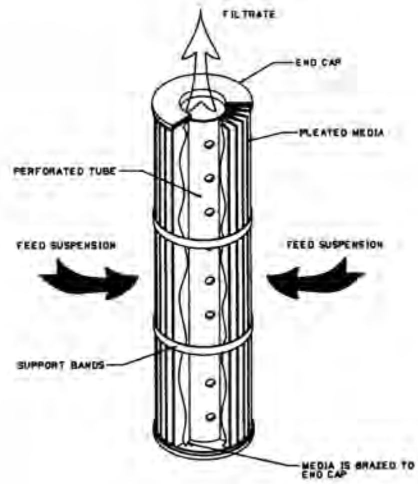

Fig. 2. Pall Filter Module.

The Pall filter module is the basic building block of the filter canister. Eleven filter modules are welded end-to-end to form a filter element. The internal drain tube of the element is plugged at the top. The drain tube at the lower end is sealed into a header and support plate. The finished filter canister consists of 17 filter elements in a concentric circular pattern (Fig. 3). The Pall filter canister has a surface area of 523 square feet.

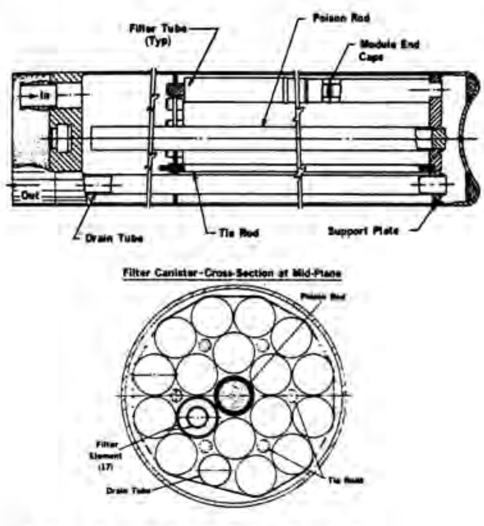

Fig. 3. Pall Filter Canister.

FILTER TESTING

The filter tests were conducted in an automated state-of-the-art filter test facility designed by B&W engineers. A schematic of the facility is provided in Fig. 4.

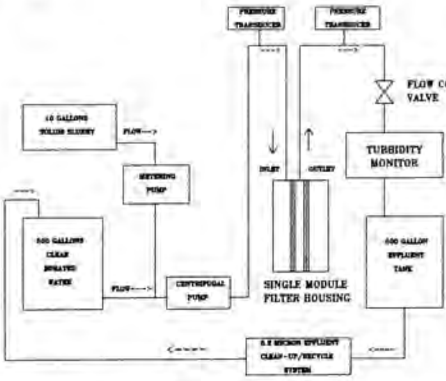

Fig. 4. Pall Filter Test System.

The filter candidates were challenged with simulated debris solids suspensions of 1400 and 140 ppm in a borated water solution (5000 ppm boron). The solids fines used included zirconium dioxide, stainless steel, iron oxide (red) and for several tests uranium dioxide was used. Test data generated includes solids loading, effluent turbidity, and differential pressure as a function of time.

The filter test parameters used are presented in Table I. The solid fines particle size distribution information is presented in Table II.

TABLE I

Filter Test Parameters

Feed Solution:	pH adjusted 5,000 ppm borated water				
Flow Density (GPM/Sq Ft)	Mott	0.5			
	Pall	0.25			
		DWCS		F/VDS	
Solids Concentration (ppm)		140		1400	
Solids Composition		ZrO_2	85	SS/UO_2	60
		Fe_2O_3	15	ZrO_2	30
				Fe_2O_3	10

TABLE II

Solid Fines Test Materials

Zirconium Dioxide	
Zirox-70	95% < 2.1 micron 40% < 0.5 micron
Zirox-250	95% < 20 micron 40% < 1.6 micron
Iron Oxide	
Fe_2O_3 (red)	95% < 1.3 micron
Uranium Oxide	
UO_2	95% < 8 micron 40% < 1 micron
Stainless Steel	
316L powder	95% < 42 micron 40% < 16 micron

TEST RESULTS

The Mott filter concept was evaluated in a series of 14 tests. These represent a total test period of 300 hours. The operation of the Mott single filter element was successfully demonstrated. The filter's effluent turbidity was less than 1.0 NTU. A final filter canister loading of 400 pounds could be projected. The turbidity and differential pressure trends for a typical Mott filter test are illustrated in Fig. 5.

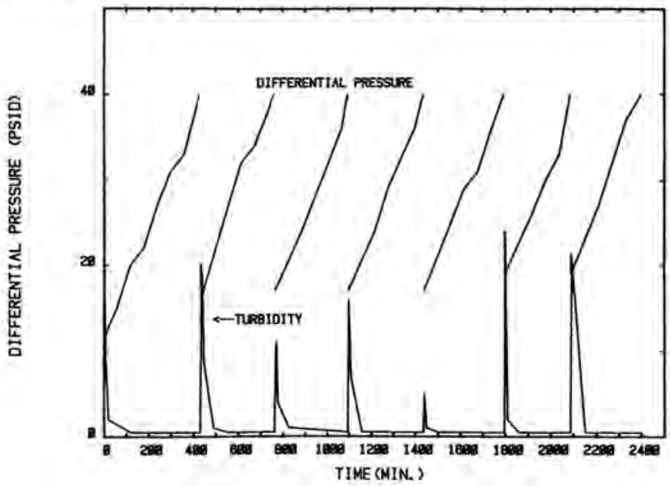

Fig. 5. Mott Differential Pressure and Turbidity Vs. Time.

The Pall filter concept was evaluated in a series of 12 tests, representing a total of 250 hours of testing. The operation of a single filter module was successfully demonstrated. The filter's effluent turbidity was maintained less than 1.0 NTU. The Pall Filter Canister can be projected to remove more than 400 pounds of debris. The differential pressure trends for a Pall filter module test are given in Fig. 6.

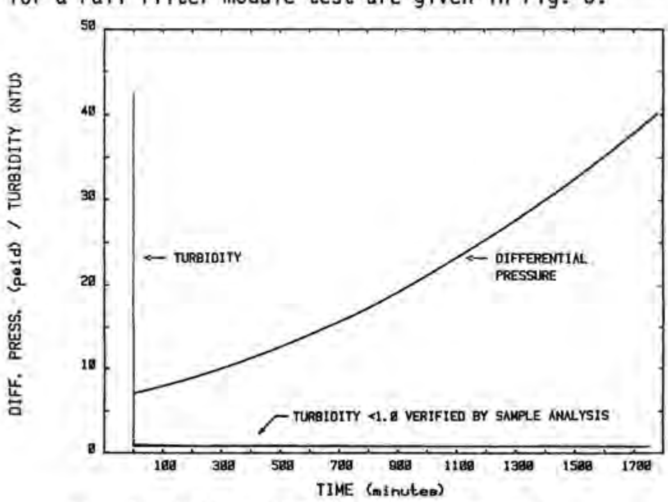

Fig. 6. Pall Differential Pressure and Turbidity Vs. Time.

A summary of the test results for each filter at 1400 and 140 ppm is given in Table III.

TABLE III

Summary of Test Results

Mott Filter Element Test Results

Flowrate: 0.5 GPM/Sq Ft, 0.56 GPM

Solids Conc. (ppm)	Cycle Time (min)	Turbidity (NTU)	Solids Loading (lbs)
1400	71	< 1.0	4.2
140	342	< 1.0	1.6

Pall Filter Module Test Results

Flowrate: 0.25 GPM/Sq Ft

Solids Conc. (ppm)	Cycle Time (min)	Turbidity (NTU)	Solids Loading (lbs)
1400	503	< 1.0	1.4
140	1755	< 1.0	1.2

CONCLUSIONS

The Pall Filter Concept offered significant advantages over the Mott Filter Concept. The Pall Filter was chosen for the final filter design based on its simplified continuous mode of operation.

The full-scale Filter Canister is designed to remove suspended solids from 800 microns to 0.5 micron. The Filter Canisters are scheduled to be in service the summer of 1985.

REFERENCES

1. P. C. Childress and E. J. McGuinn, "TMI-2 Core Removal Program Defueling Canister Design," Waste Management '85, 1985.

2. K. B. Rao and W. H. Bell, "Developments in Backwashable Fine Filter," Waste Management '84, 1984.