OPERATIONAL EXPERIENCES OF NON-PRECOATED TYPE FILTERS (SUPER FINE FILTER) IN PWR AND BWR NUCLEAR POWER PLANTS

Y. Koshiba and T. Nakatani
JGC Corporation, Nuclear Project Division
Yokohama, Japan

H. Kuribayashi and N. Kurosaka
JGC Corporation, Oharai Nuclear Research Center
Oharai, Ibaragi, Japan

ABSTRACT

Precoated and cartridge type filters which are conventionally used in Japanese LWR nuclear power plants still have a disadvantage of generating a large amount of spent filter media as secondary waste. In addition to that, they are insufficient in separation performance and require frequent maintenance resulting into radiation exposure to personnel. In order to resolve these problems, the Super Fine Filter (SF filter) has been successfully developed and applied at many Japanese LWR nuclear power plants. This paper describes the results of the R & D work and operational experiences of the SF filter at nuclear power stations.

BACKGROUND

The SF filter, originally, has been developed by KURARAY CO., LTD. in Japan and already applied to water treatment in food industries or ultra pure water manufacturing processes.

In 1980, JGC started R & D work on the SF filter to explore its application for radioactive liquid waste treatment in Japan.

Prior to above R & D program, JGC had developed a membrane filter named NPMF (Nuclepore Membrane Filter) which has been successfully applied for the radioactive liquid waste filtration at Japanese four BWR and five PWR nuclear power plants. The NPMF has satisfactory performance in terms of particle separation and backwash durability, but still has a disadvantage of rather expensive plant cost.

For example, as the treatment capacity of individual NPMF housing is small (5 - 10 m^3/hr), plural housings (2 - 4 housings) are required to achieve average treatment capacities (20 - 40 m^3/hr) in LWR nuclear plants.

Multiple housings require not only an increase in the number of pipings, valves and instruments but also larger space and replacement work for the plural filter elements.

On the other hand, the SF filter, as described hereinafter, has excellent filtering and backwashing performance and flexible capacity in a single housing between one to several hundred cubic meter per hour. Thus, it surely reduces the plant cost and increases reliability of operation. The SF filter has already been selected in Japanese three BWR plants and a PWR plant and some of them have started their actual operations.

CHARACTERISTICS OF THE SF FILTER

The SF filter consists of porous hollow fiber made of modified poly-vinyl alcohol. In addition, the SF filter, a non-precoated type filter, does not generate such secondary waste as spent precoat material. The specifications of the SF filter are described in Table I and it's configuration is shown on Photos. 1, and 2.

TABLE I

Specifications of SF Filter

Material	Poly-vinyl alcohol
Membrane type	Hollow Fiber Inner diameter 0.4mm Outer diameter 0.9mm
Pore size	0.04 micro-m (90% rejection)
Module size	Length 1.000mm Diameter 80mm
Effective membrane area	approx. 7m^2/module
Filtration flux	1~2m^3/hr.module

The hollow fiber is of a cylindrical shape of approximately 0.9 mm outer diameter and 0.4 mm inner diameter as shown in Photo. 1. The major pore sizes of the membrane distribute under 0.1 micron meter, and fine particles which we frequently encounter at nuclear power stations can be completely removed from liquid wastes.

A single module consists of approximately 3,000 hollow fibers of one meter length. The top ends of the 3,000 hollow fibers, bound by epoxy resin, are open and the bottom ends of the fibers are sealed by an epoxy resin adhesive as shown in Photo. 2.

One module has approximately 7 m^2 of effective filtering surface area, and standard filtering capacity is designed at 1 m^3/hr.

The necessary number of modules between one to several hundred are installed in one housing depending on the design capcity.

The module has rejection performance over 90% for 0.04 micron meter particles or larger.

Photo. 1. Cross-sectional View of Fiber

Photo. 2. Side and Top Views

It has been observed that particles such as CRUD contained in the liquid waste are removed at the outer surface of each hollow fiber by passing the liquid waste from the outer surface to the inner hollow path of the fiber.

The filtering operation will be automatically forced to stop immediately after the pressure drop reaches to the pre-set value and backwashing operation by air flowing in the reverse direction commences.

CRUD trapped on the outer surface of the hollow fiber are removed from the surface by the air flow itself and shaking action of fibers caused by air bubbling.

Removed CRUD is suspended in the liquid remaining in the housing and drained out of the bottom nozzle. Filtering operation restarts immediately upon completion of ten minute backwashing operation.

The material, structure and operation of the SF filter described above introduce following excellent characteristics.

1. Perfect particle separation
2. Long filtering and backwashing durability
3. Reduction of secondary solid waste
4. Reduction of installation, operation and maintenance costs.

RESULTS OF R & D WORK

Chemical and physical properties of the hollow fiber were tested to evaluate the applicability of the SF filter to nuclear power plants.

In-plant tests were also conducted to confirm stable and safe operation for frequently changing nature of the various liquid waste streams.

Physical Properties

Pressure and temperature durability of the hollow fiber were measured at JGC's Oharai Nuclear Research Center.

Radiation stability was also measured at the Center after gamma and beta irradiation.

(1) Temperature Durability

Flux with clean water is shown in Fig. 1 for various water temperatures.

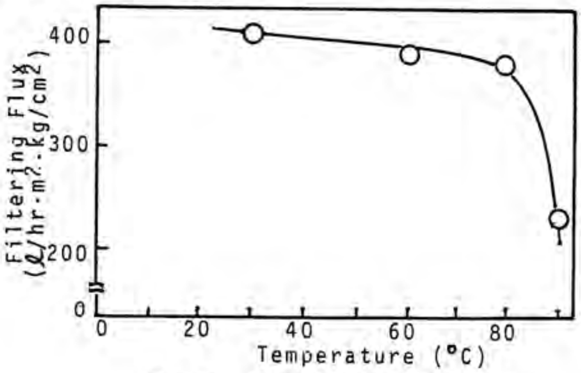

Fig. 1. Temperature Durability

The flux of the fiber decreases at the temperature over 80°C but it maintains sufficient durability below 80°C.

(2) Pressure Durability

A number of modules were tested in single module housings and water was injected at temperatures between 10°C to 70°C and filtering pressures were increased until the hollow fibers of each module were burst by the applied water pressure.

Two series of bursting pressures were recorded at the moment when the hollow fibers were broken by the differential pressure applied along the filtration direction and reverse direction.

The bursting pressures measured in the above experiments are plotted in Fig. 2.

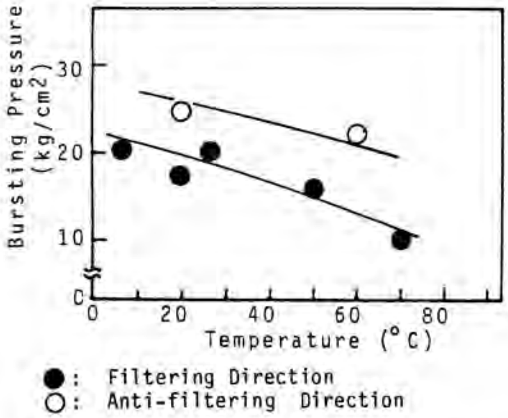

Fig. 2. Bursting Pressures of the SF Filter

It was confirmed that the bursting pressures were different from the direction of water flow and decreased at higher temperatures.

(3) Radiation Stability

Changes in tensile strength and filtration flux of module were measured after β and γ ray irradiation in the range of 10^6 to 10^8 R.

Tensile strength of hollow fibers are plotted in Fig. 3.

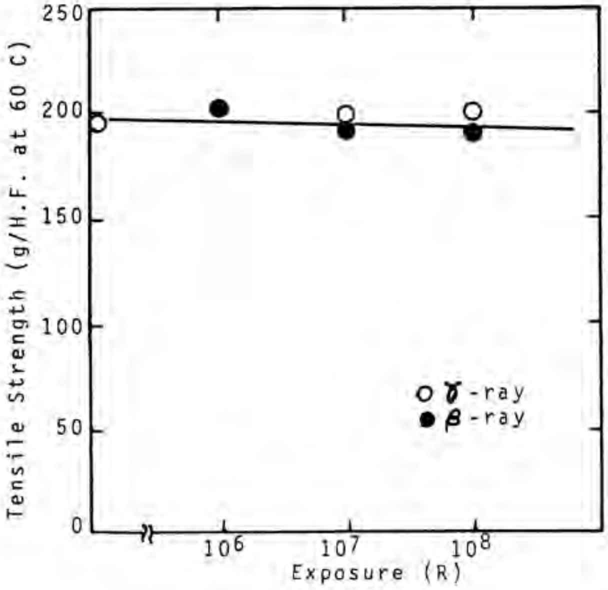

Fig. 3. Radiation Stability

The hollow fibers have good stability against β and γ irradiation up to 10^8 R.

Chemical Properties

Tensile strength of hollow fibers was measured after dipping in typical chemicals including acids (HCl, HNO_3, H_2SO_4, H_3PO_4, H_2BO_3) and alkalis ($NaOH$, NH_4OH) for a month. The hollow fiber is resistant to these chemicals within a wide pH range of 1 to 14.

Backwash Durability

Two kinds of backwash durability tests had been conducted to confirm physical strength against the hollow fiber's shaking action by the backwash air flow.

One module was installed in a single module housing and repeated backwash operation about 3,800 times in 126 hours.

The other module was backwashed about 200 times during longer filtration hours (9,000 hours).

During these tests, the hollow fibers were periodically sampled and measured with their tensile strength.

The tests results are described in Fig. 4.

The tensile strength of each hollow fiber was almost the same as that of the new one.

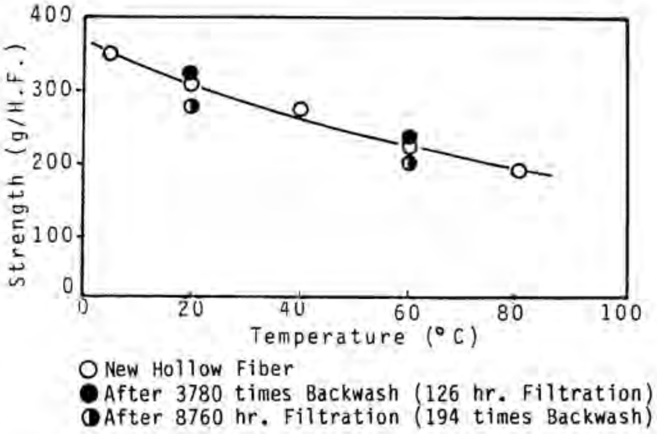

Fig. 4. Backwash Durability

IN-PLANT TESTS

In-plant tests at a PWR and two BWR plants for filtering respectively refueling water and low conductivity liquid waste were successfully completed in Japan.

In this paper, results obtained at an in-plant test conducted at a BWR plant using low conductivity liquid waste are reported in detail.

The test was started in January 1984 and completed in December 1984. The test conditions and properties of treated liquid waste are described in Table II and III.

TABLE II

Test Conditions

Filtering capacity	1 m^3/hr
Pressure drop increase until each backwash	0.3 kg/cm^2
Backwash air pressure	3 kg/cm^2G
Backwash operation duration	10 minutes

TABLE III

Suspended Solid Concentration in Treated Water

Kind of Waste	Turbidity (ppm)
- Equipment drain	1
- Backwash waste of condensate demineralizer	50
- Decant water of spent powdex storage tank	30
- Distallate of evaporator	1
- Miscellaneous blowdown water	100

During the test, filtering pressure drop and suspended solid concentration at inlet and outlet of the SF filter were periodically measured and plotted as in Fig. 5 and 6.

Suspended solid concentration at the inlet of the SF filter was ranged between 1 to 15 ppm and that of outlet was constantly below the detectable limit throughout the test.

However, net filtration duration between each backwash were fluctuated in the range of 10 to 50 hours.

Each filtration duration or backwash frequency seemed to be related to the reactor operating conditions rather than suspended solid concentration at the inlet of the SF filter.

Especially, the filtration duration was distinctively shortened and initial pressure drop after each backwash increased during the start up period of the reactor.

Initial pressure drops after each backwash were major concern of these experiments as they usually determine module life.

As the results from this experiment, the module life is estimated at least three to five years.

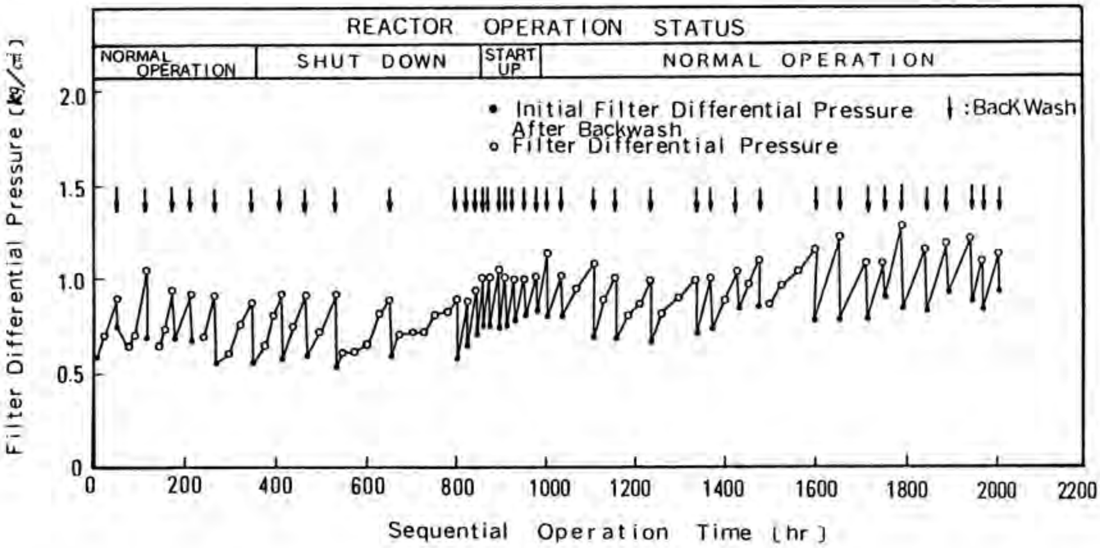

Fig. 5. Pressure Drop of the SF Filter

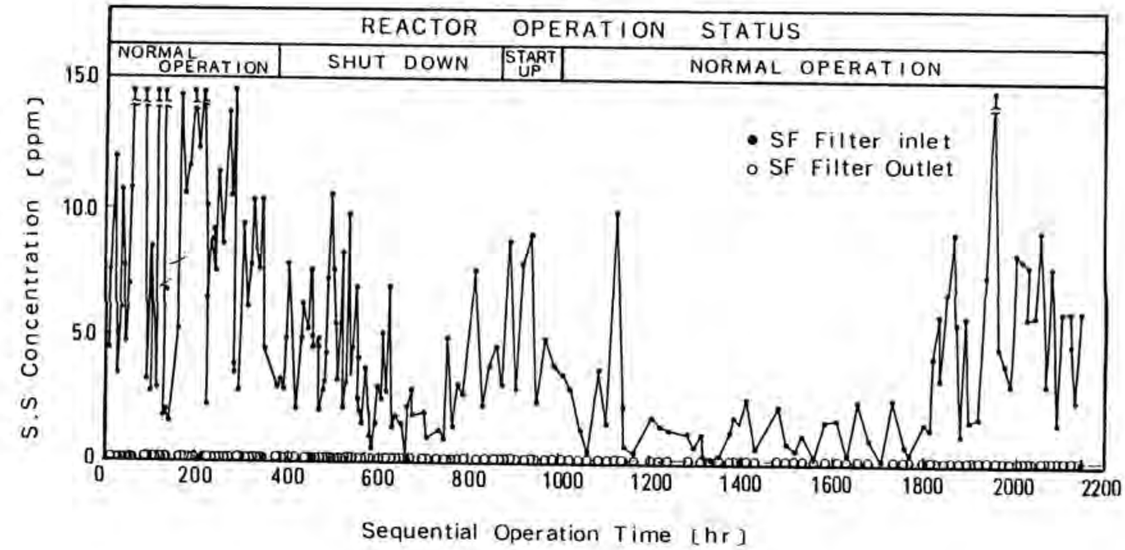

Fig. 6. Suspended solid concentration at inlet and outlet of the SF filter.

CONCLUSION

The SF filter has been developed to attain improved filtering performance and less secondary solid waste generation.

Its basic properties such as physical and chemical durability are satisfactory for actual application to nuclear facilities.

In-plant test results show that the SF filter has excellent filtering and backwashing performance and its life is estimated at more than three years. Such successful research and development has led to accelerated actual application of the SF filter to nuclear facilities in Japan.

The two commercial SF systems have been designed and operating. One of them has already started operation at a BWR nuclear power plant for the treatment of low conductivity liquid waste and the other one has been put at a PWR power plant for clarification of refueling water.