ADVANCED RADWASTE SYSTEM

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ABSTRACT

An advanced radwaste system utilizing new volume reduction processes has been proposed for LWR power plants, from the standpoint of the wastes generated and their volume reductivity.

The volume reduction processes selected include incineration, wet oxidation of ion-exchange resins, recycling process for regenerant waste, reverse osmosis process for floor and laundry drains, and the use of a non-precoated filter. The effects of introducing these processes are discussed in detail along with some test results.

INTRODUCTION

At present, the advanced LWR system is being designed to improve the availability factor, operating performance, maintenance and standardization. Accordingly, there is a great demand for an improved radwaste system. The advanced LWR, especially for BWR, radwaste system must take the following points into consideration in planning and designing:

(1) Reduction in radwaste generation and volume

(2) Reduction in radiation exposure to personnel

(3) Reduction in activity release into the environment

(4) Energy conservation

Specifically, to reduce the radwaste generation, the following measures must be considered:

- Measures to be implemented at the generation sources (regeneration liquid waste recycling process, non-precoated filters, etc.)
- Measures for converting generated (organic) radwaste into volume-reduced (inorganic) matter (decomposition of spent resin).

The results of the experiment concerning the above two items will be described in detail.

JGC'S ADVANCED RADWASTE SYSTEM

Simplified flow sheets of an average BWR radwaste plant in Japan and JGC's advanced BWR radwaste plant are shown in Figs. 1 and 2, respectively. A comparison between those two plants are as follows:

Between the present and advanced radwaste systems, there are no substantial differences in the equipment drain subsystem. CRUD, removed with the non-precoat filter, will be initially stored in tanks, and solidified after the decay of radioactivity. The non-precoat filters used in these systems are NPMF (Nucle-pore Membrane Filter) and SF (Super Fine) filter, whose many features meet the requirements for liquid waste treatment. Further description on the effects of the SF filter will follow later in this report.

In the advanced radwaste system, floor drain is treated with reverse osmosis (RO) instead of the conventional evaporator in order to minimize corrosion problems. Treated water (permeate) is discharged into the environment, and concentrated (rejected) liquid waste by the reverse osmosis process is evaporated together with the other liquid chemical wastes in a small evaporator. Condensate from the evaporator will be reused in the power plant and the concentrated liquid will be solidified in the solidification subsystem.

For regeneration waste of the advanced system, the amount of liquid waste generated is diminished by the recycling process which recovers and reuses the regenerants (sulfuric acid and sodium hydroxide). After the regenerants have been recovered, the remaining liquid waste will be concentrated by an evaporator, together with a small amount of concentrated reverse osmosis waste in the floor drain subsystem. They will then be treated in the solidification subsystem.

Should the reverse osmosis process be applied to floor drains and the recycling process to the regeneration waste, the load for a waste evaporator can be minimized considerably.

Spent resins and filter sludges are decomposed into inorganic matter and thereby reduced in volume. Only very small amounts of off gas is discharged into the atmosphere and the decomposition residues are solidified at the solidification subsystem.

In the advanced system mentioned above, most of the radioactive wastes to be solidified become inorganic matter, amounting to approximately 10 tons per year in dry form (except incombustible miscellaneous solids and core internals). The original amount of those wastes are approximately 100 tons per year for an 1,100 MW BWR. Should these wastes be packaged at the rate of 100 to 200 kg per drum, the number of drums per year will amount to approximately 50 to 100 for the advanced system compared with 500 to 1,000 for the reference system. Since the surface dose rate of these drums becomes 20 to 40 times as high, an extremely efficient and reliable solidification facility capable of handling such levels of radioactive wastes must be selected.

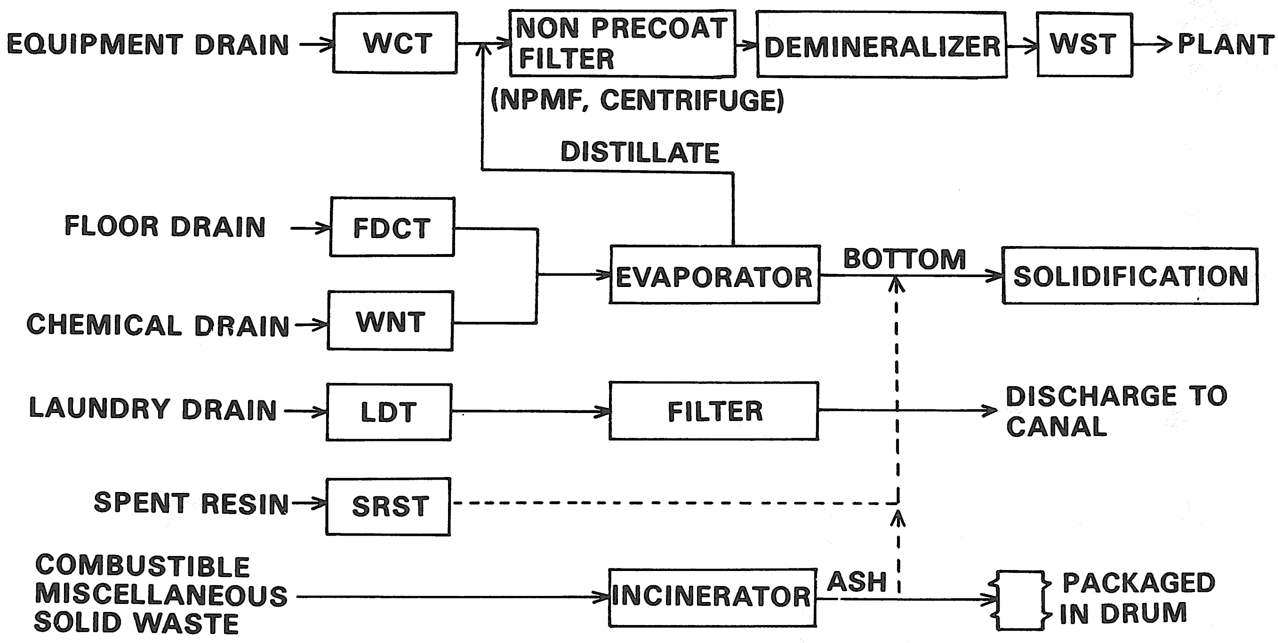

FIG. 1 RADWASTE SYSTEM AT PRESENT

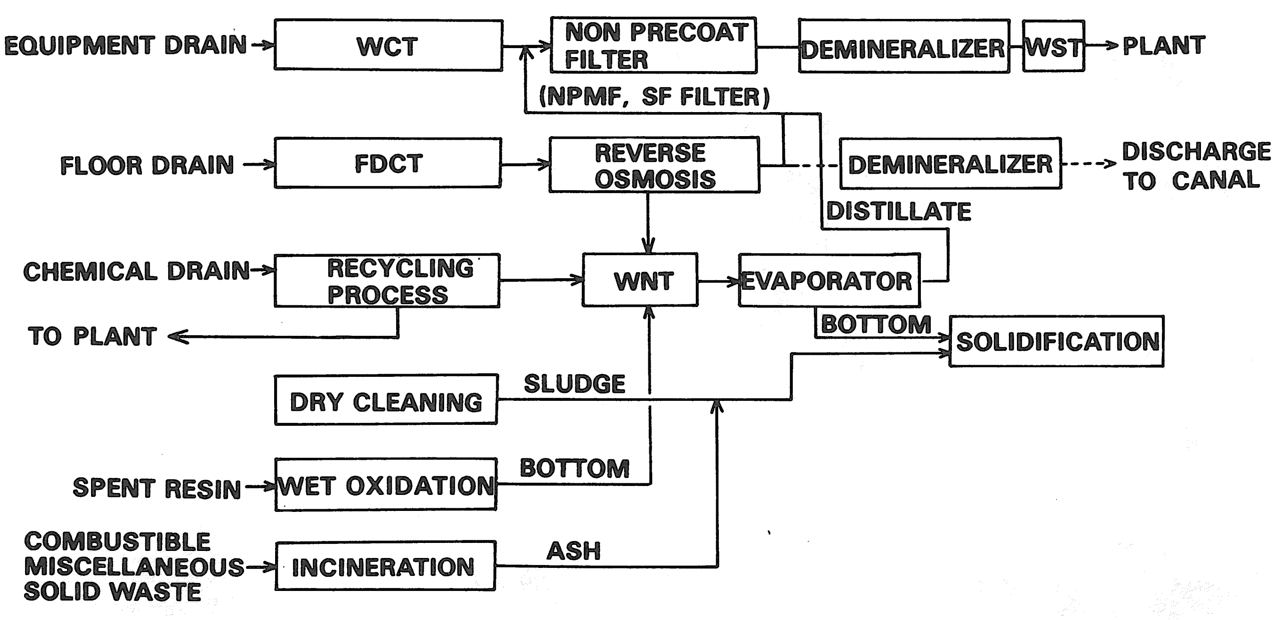

FIG. 2 JGC'S ADVANCED RADWASTE SYSTEM

VOLUME REDUCTION IN THE ADVANCED RADWASTE SYSTEM

In Fig. 3., the volume reduction in the advanced radwaste system is shown. Since the volume of given radwastes is correlated to their weight, and weights in a dry form can be defined more accurately than in a volume basis, the discussion in this chapter will refer to weights. Thus, the weights of the original radwaste in an 1,100 MW BWR plant and those weights after the application of each of the volume reduction techniques are compared on a dry basis, excluding incombustible solid waste.

The weight of the original radwaste is about 110 tons per year per unit, but after the installation of an incinerator, this is reduced to approximately one half of the original weight (Stage 1). At this stage, the major components of the radwaste consist of spent resin from the demineralizer and Na_2SO_4 from the regeneration of the demineralizer.

With the adoption of the decomposition technique or spent resin (Stage 2), Na_2SO_4 will constitute the major portion of the radwaste.

After the recovery of sulfuric acid and sodium hydroxide from the spent regenerants of the demineralizer for re-utilization as regenerants (recycling process), the final radwaste weight will be reduced to approximately one tenth of its original weight (Stage 3).

These two techniques, recovery of the regenerants and decomposition of spent resin, have been developed for future application.

When radioactive wastes are reduced in weight or volume to the extent mentioned in Stage 3, the residues, which consist only of CRUD and mixed inorganic salts, are almost impossible to further separate and recover.

DEVELOPMENT STATUS AND EXPERIMENTAL RESULTS OF EACH PROCESS OF THE ADVANCED RADWASTE SYSTEM

Incineration

JGC managed, from the basic design to its construction, Japan Atomic Energy Research Institute's (JAERI) incineration system. JAERI has, since 1973, successfully continued operations.

The furnace at this particular system has four chambers, of which the primary and secondary chambers are each equipped with a burner. The primary chamber of the furnace has a combined structure of a flat floor and a grate to enable both paper and plastic materials to be well incinerated.

The solid wastes charged into the primary chamber are partly pyrolyzed into gases on the floor. While passing through the secondary, tertiary and final chambers, the gases are thoroughly burned. The solids remaining in the primary chamber are completely burned and are then removed through the ash outlet.

Flue gas from the furnace is indirectly cooled by air, followed by a dry electrostatic precipitator and a HEPA filter. During the operation, the radioactivity of the discharged gas was monitored at the exit of the stack and measured less than 1×10^{-14}micro-Ci/cm^3.

Wet Oxidation

The above-mentioned incineration is conducted at high temperatures (600°C - 1,000°C). However, wet decomposition of organic matter easily takes place in an aqueous phase in the presence of the catalyst and hydrogen peroxide. This reaction occurs at a low temperature of 100°C.

At present, a continuous type pilot plant with a capacity of 1.0 kg-dry resin/hr and a batch type pilot plant with a capacity of 3.5 kg-dry resin/hr are being operated.

Experimental results are as shown in Fig. 4 with the batch operation flow of this process shown in Fig. 5. The decomposition is conducted as shown below.

(1) One batch amount of sludge in slurry state is withdrawn from the storage tank and fed to the reaction vessel without any pretreatment, such as dewatering or drying.

(2) The reaction vessel is heated to 100°C and hydrogen peroxide is added to the sludge in the vessel at a pre-set feed rate.

(3) The specified reaction conditions are maintained from 1 to 4 hours during which the sludge is decomposed into water and carbon dioxide.

(4) The reaction residue is treated in the existing concentrator (or a concentrator provided for its exclusive use) and is transferred to the solidification system.

The features of this process can be summarized as follows:

(a) Since organic matters in the filter sludge and spent resin can be completely decomposed, the volume reducibility is very high.

(b) Since the reaction develops in the water, the filter sludge and spent resin need not be dewatered before feeding to the reaction vessel.

(c) Because the reaction occurs in an aqueous phase, negligible radioactivity is transferred into the vapor phase; that is almost all the radioactivity is left in the reaction residue.

(d) The system is rather simple, consisting chiefly of the reaction vessel. It does not need any off gas scrubber.

(e) Maximum safety conditions are expected, since the reaction can be conducted at mild conditions of 100°C under the atmospheric pressure.

Recycling Process

This technology is intended to reduce the quantity of concentrator bottoms by recovering regenerants (sulfuric acid and sodium hydroxide) with electro-dialysis (using an ion-exchange membrane) from liquid waste, i.e. spent regeneration solution. This waste is generated in the regeneration of the ion-exchange resins in the demineralizers used in the

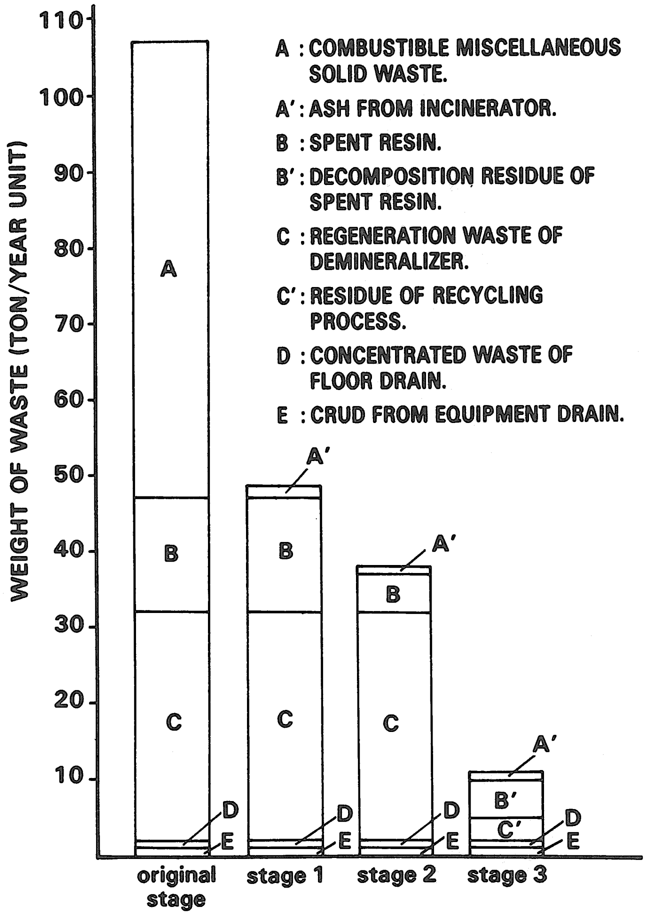

FIG. 3 RADWASTE VOLUME REDUCTION
(DRY WEIGHT OF WASTE)

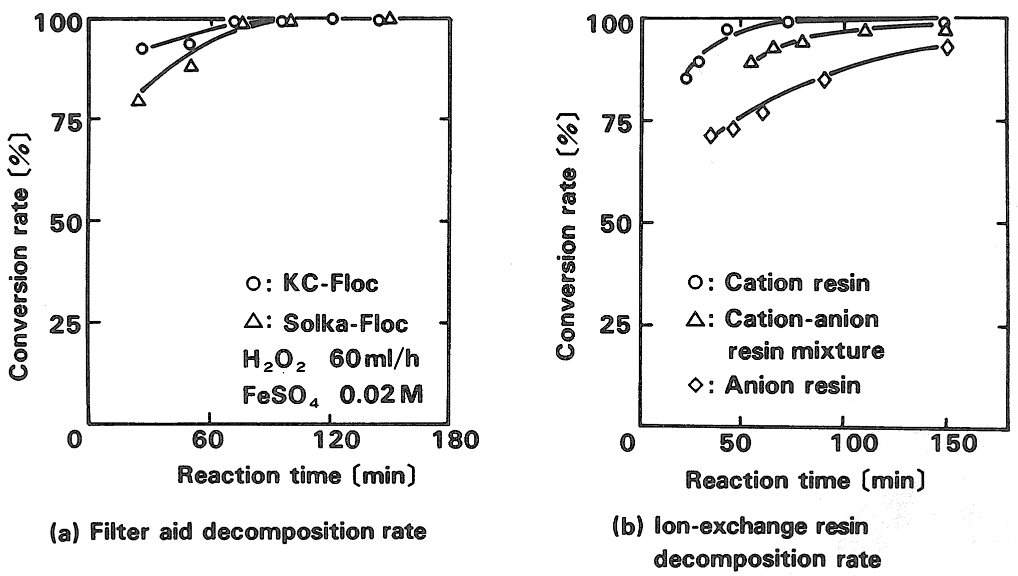

FIG. 4 EXPERIMENTAL RESULTS

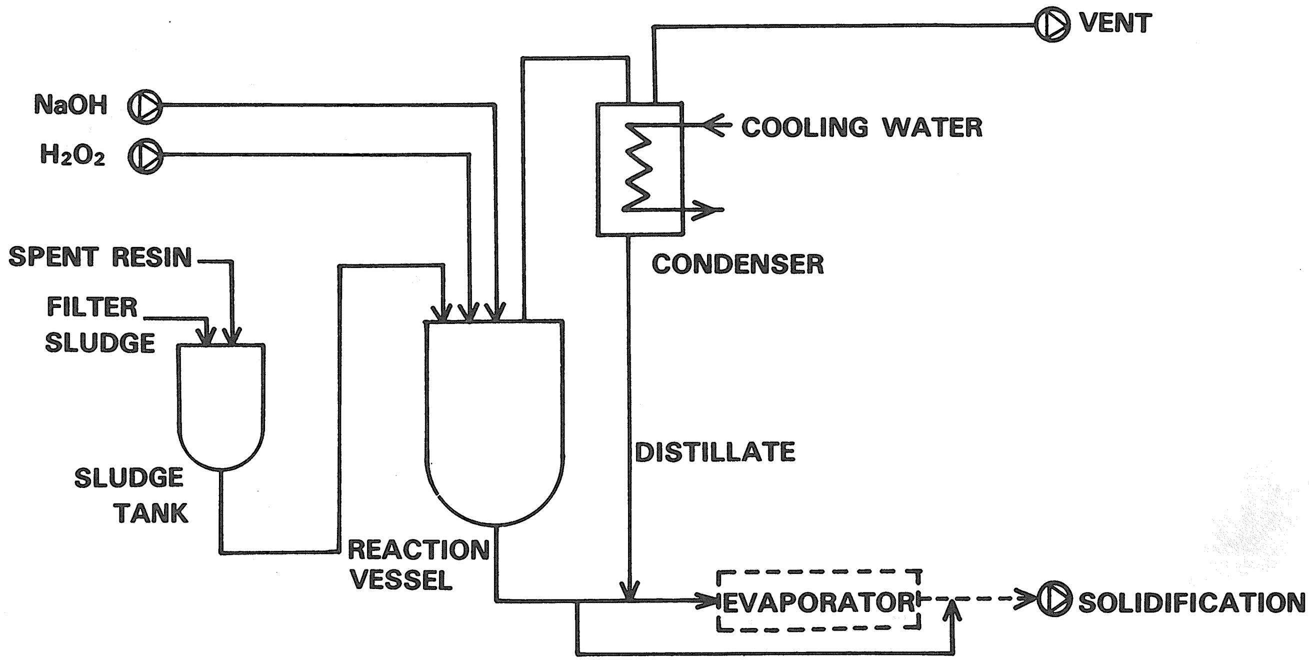

FIG. 5 FLOW SHEET OF WET OXIDATION

condensate polishing and waste treatment system of a BWR plant.

Regarding this technology, hot tests were conducted in a pilot plant by using anion and cation regeneration liquid wastes actually obtained in a BWR plant.

The results of those tests are as shown in Table I.

Reverse Osmosis

To conserve energy, reduce oncentrator load and avoid corrosion difficulties, an attempt has been made to apply a reverse osmosis (RO) technique to the treatment of various liquid wastes.

JGC has developed an application which is a combination of reverse osmosis and electrodialysis for the treatment of radwastes, such as supression pool water containing corrosive ions at higher concentrations. One 3 m^3/hr RO system was installed at Tokyo Electric Power Co., Ltd.'s No. 1 Fukushima Nuclear Power Station with its commercial operation continuing since September 1, 1981.

Floor drains, such as that shown in Fig. 6, is considered to be suitable for RO, in which a SF filter is used in the pretreatment. From this RO system, concentrated liquid waste is sent to a chemical drain subsystem and RO permeate to an equipment drain subsystem.

A pilot plant with a capacity of 1 m^3/hr was installed and three months of cold operation tests and six months of hot operation tests were completed from 1981 to 1982 at the nuclear power station.

To apply the RO system to a laundry drain, coagulation-sedimentation has to be introduced for the pretreatment of the drain to avoid fouling of the RO membrane adopting hollow fiber modules. In order to avoid foaming, activated carbon adsorption may also be recommended for the post treatment of RO brine prior to feeding it to an evaporator for further concentration. This process flow is shown in Fig. 7.

This process has been demonstrated by conducting a long hot run with a pilot plant for treatment of actual laundry drain generated at a BWR power station.

SF Filters

The SF filter is a product manufactured and marketed by Kraray Co., Ltd. which consists of many hollow fibers made of synthetic polymer (modified polyvinyl alchol). Its special features are:

(1) The excellent stability against an enormous variety of alkali or acid chemicals and organic solvents.

(2) The hollow fiber shape which gives large filtering surfaces per housing volume and installation space.

(3) The removal of 0.1 micron in diameter particles at a rejection efficiency of up to 99%.

(4) The filtering performance which is recovered by back-washing with air and/or water, so that the same filter modules can be used for long periods of time.

(5) The gamma-ray radiation up to 10^8 Rad which does not appreciably reduce its tensile strength.

An element of the SF filter consists of approximately 3,000 hollow fibers bundled at the top end by epoxy resin. A single fiber is 0.8 and 0.4 mm in OD and ID, respectively, and approximately 1 m in length. The bottom end of each fiber is plugged by an adhesive, with the top end left open.

The typical housing is shown in Fig. 8. For processing a large amount of liquid, plural elements can be housed in a proper diameter housing, so that only one housing will always suffice. There is no need to install several housings for the capacity below several hundred cubic meters per hour.

The filtration of the SF filter occurs under external pressure. The liquid to be filtered is brought around the hollow fibers under pressure. Suspended matter in the liquid is rejected at the outer surface of the fibers, while clean water passes through the fiber and is collected at the top of the housing.

Results of the SF filter tests with various liquid wastes are shown below.

Regarding BWR floor drain, a hot test was conducted for three months in a 1 m^3/hr pilot plant. As a result of this test, the competent performance of the SF filter was confirmed.

Hot tests are currently being conducted, also in a 1 m^3/hr pilot plant, on BWR equipment drains.

In a PWR plant, a 12 m^3/hr SF filter unit was used for the clarification of refueling water in which excellent results were obtained. After the test, practical operation has been conducted for more than one year with no difficulties.

In all the tests, the suspended solid (SS) concentration at the outlet was less than the detectable limit.

Results of the durability test are as shown in Fig. 9. The differential rise in pressure after each back-washing is minimal even after 10,000 hours of operation.

CONCLUSION

Hot tests for all of the aforementioned processes will be completed on a pilot scale and the units for commercial use will be designed within one or two years.

The adoption of all or part of these processes will vary depending upon the particular plant involved, (a PWR or BRW), and the individual circumstances and needs of the plants. The final decision for adoption of the advanced radwaste system technology will be the overall cost factor, including both processing and disposal costs.

However, our trial calculations indicate that although the initial costs of such a system is high, it appears to be the most economical for countries such as Japan, where disposal costs are expected to be very expensive and rise even further with time.

Table I. The Result of the Test

Regeneration Liquid Waste	Cation H_2SO_4	Anion NaOH
Purity of regeneration agents recovered	99.7%	99.9%
Recovery rate	93.1%	98.4%
Current efficiency	87.5%	92.9%

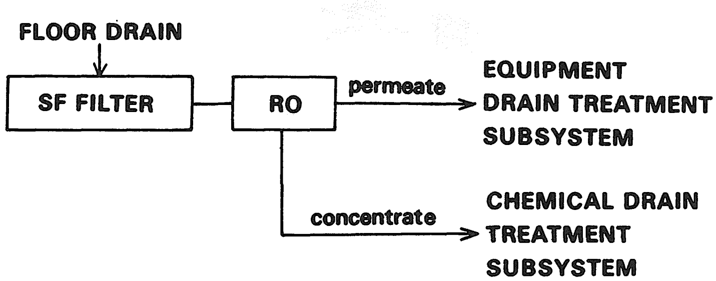

FIG. 6 REVERSE OSMOSIS PROCESS FOR FROOR DRAIN

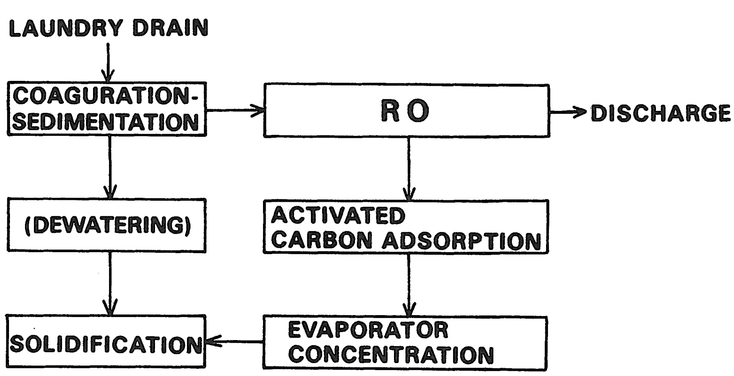

FIG. 7 REVERSE OSMOSIS PROCESS FOR LAUNDRY DRAIN

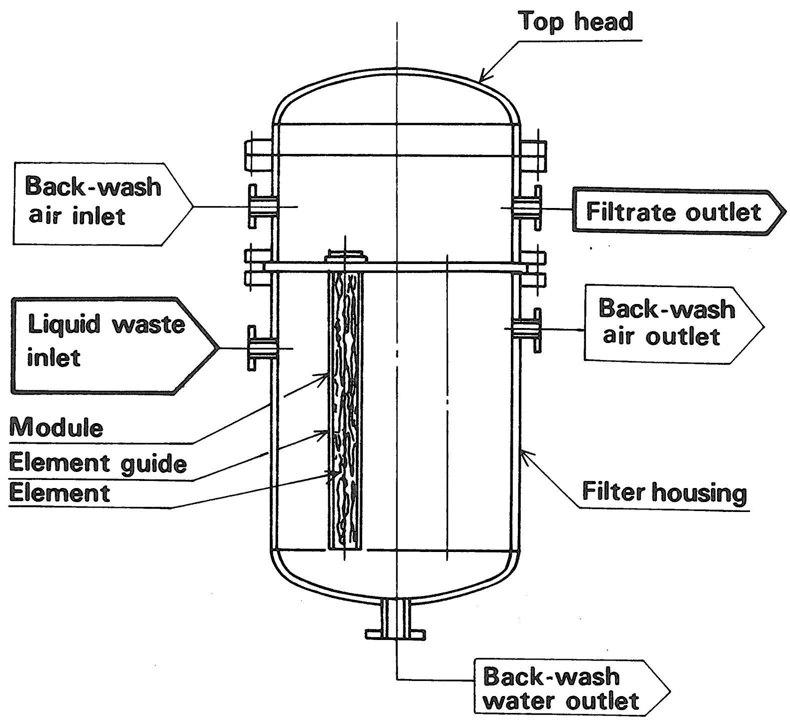

FIG. 8 CONSTRUCTION OF SF FILTER

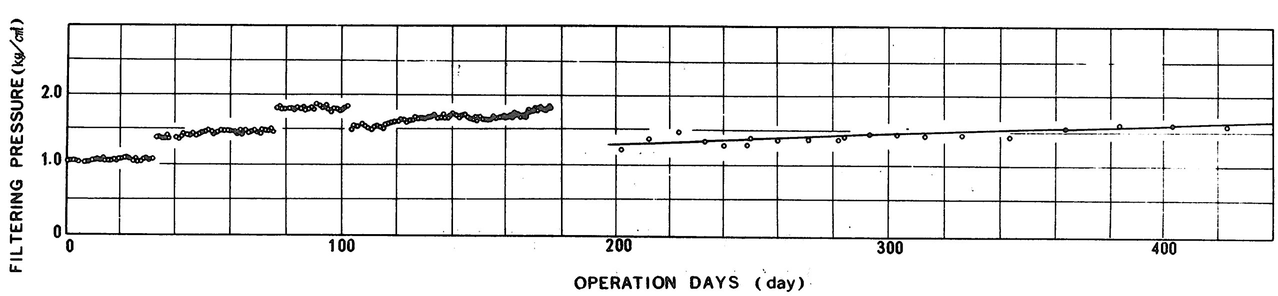

FIG. 9 DURABILITY TEST RESULT