THREE MILE ISLAND UNIT 2
DRY-CANAL DEFUELING WATER CLEANUP SYSTEM--AN UPDATE

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ABSTRACT

During the defueling phase of the Three Mile Island Unit 2 (TMI-2) cleanup effort, the reactor vessel (RV) with internals indexing fixture (IIF), the refueling canal, and the spent fuel pool will be partially filled with water to enable the fuel transfer operation to occur safely. This water must be maintained at a Cs-137 concentration of 0.01 to 0.02 µCi/ml and a clarity level of approximately 1 nephelometric turbidity unit (NTU). These criteria were selected to ensure that radiation dose rates to workers one foot above the defueling platform are maintained as low as reasonably achievable (ALARA), and to maintain sufficient water clarity to allow workers to see underwater components in the vessel, refueling canal, and spent fuel pool during the defueling operation.

A defueling water cleanup system (DWCS) has been designed to meet these objectives. Two subsystems constitute the DWCS. One subsystem processes water within the vessel/internals indexing fixture (a cylindrical extension of the vessel) with a 400 gallons-per-minute (gpm) design basis flowrate for filtration and a 60 gpm flowrate for ion exchange. The other subsystem processes refueling/spent fuel pool water with a 400 gpm filtration system and a 30 gpm ion-exchange system.

BACKGROUND

During disassembly and defueling of the TMI-2 reactor it will be necessary to fill the reactor vessel, the deep end of the refueling canal, and spent fuel storage pool "A" with water from the borated water and processed water storage tanks. The water in the reactor vessel, refueling canal, and "A" pool must be maintained at sufficiently low radioactivity concentrations (particularly with respect to Cs-137) to maintain ALARA radiation exposure to workers on the defueling platform and in the fuel handling building. In addition, water clarity must be maintained in these areas so that the underwater components can be seen.

Recent data indicate that a thorough mix of a debris sample taken from the reactor coolant system (RCS) results in turbidity as high as 100 NTUs. A four- to five-day settling period is required to reduce the turbidity to 10 NTUs, indicating the need for an effective filter for turbidity reduction.

Also, it is anticipated that cutting operations during disassembly of fused and deformed components in the core will generate a substantial amount of additional debris. Cutting operations and fuel and debris removal may also cause a significant degree of water agitation, which could suspend previously settled particles in the reactor vessel.

In addition to foreseen turbidity problems, the fission products will leach into the RCS.

Soluble Cs-137 will be the primary cause of radiation exposure to personnel on the defueling platform above the vessel and in the fuel handling building near spent fuel pool "A". A Cs-137 concentration of 1 µCi/ml in the water will result in a dose rate contribution of approximately 1R/hr at a distance of 1 foot above the water. As recommended by the Final programmatic environmental impact statement, the defueling water cleanup system will maintain the dose rate contribution from the water at approximately 10mr/hr to 20mr/hr, which corresponds to a Cs-137 concentration of 0.01 µCi/ml to 0.02 µCi/ml.

The build-up of antimony (Sb-125) is another concern related to increased radiation exposure to personnel. The zeolite ion-exchangers, effective for cesium removal, do not remove Sb-125. Therefore, the Sb-125 concentration increases steadily with time. When the Sb-125 level reaches an administrative limit, EPICOR II will be used to reduce antimony levels to within specified limits.

In parallel with the development of the DWCS, a new defueling concept was under development by the Expedited Defueling Task Force (an onsite group) (see Fig. 1). This defueling concept requires flooding of the deep end of the defueling canal before plenum lift, and leaving it flooded throughout the defueling process. The RV and the IIF are also flooded. The shallow end of the canal is dry.

The following criteria were used as a basis for the evaluation of various DWCS processing options:

- The soluble fission product ion-exchange media shall be used in a manner that will ensure that spent resin beads will be suitable for temporary onsite storage in the TMI-2 interim waste storage modules and can ultimately be disposed of using current shipping and handling procedures.

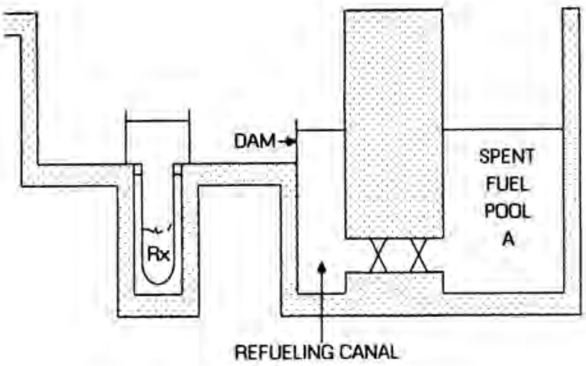

Fig. 1. Early Defueling Lay-out.

- o RV and IIF filtration systems will be designed to be compatible with the material handling techniques developed to transport solids into fuel canisters. The filters will be capable of using commercially available filtering equipment to remove fuel fines and debris above a nominal 0.45 micron rating.

- o The filtration systems will be capable of maintaining the steady-state turbidity at 1 NTU or less in the quiescent reactor vessel/IIF and spent fuel pool "A". The effluent from all water processing systems shall also be less than 1 NTU.

- o The soluble fission product processing system shall be designed to maintain the dose rate contribution from Cs-137 in the water at ~10mr/hr one foot above the water surface. This corresponds to a Cs-137 concentration of ~0.01 μCi/ml during defueling and disassembly operations.

- o Processing system suction will be taken from and effluent will be returned to the reactor vessel/IIF filtration systems in a manner that promotes downward flow above the core. This will keep the water barrier in the upper section relatively clean and will enhance shielding and visibility.

- o To support continuous flow processing, provisions for in-line monitoring of boron concentrations and pH will be used in addition to the scheduled periodic sampling of water chemistry parameters. Continuous flow systems were selected rather than batch type feed-and-bleed operations because: 1) continuous flow allows the fastest recovery time from upset conditions; and 2) continuous flow requires no intermediate tankage, thus reducing equipment and space constraints.

- o Water chemistry requirements have been developed for the reactor vessel to ensure materials compatibility. Chemistry for the reactor vessel, refueling canal, and spent fuel pool shall be based on the following parameters:

Boron	approximately 5050 ppm
pH	~7.5
Na	~1500 ppm (typical to maintain pH)
Cl^-	≤5 ppm
F^-	≤1 ppm

- o The system must be able to process reactor vessel/IIF water at a minimum continuous flow rate of 20 gpm to maintain dose rates at an acceptable level on the defueling platform. In order to maintain the 20 gpm flow rate, sufficient equipment redundancy must be incorporated into the system to ensure that no single component failure will render the system inoperable or retard the flow rate to less than 20 gpm.

- o The type of ion-exchange medium to be analyzed is zeolite resin beads. (A successful operating history on site has been demonstrated.)

The DWCS will be required to maintain water quality with respect to turbidity and radiation exposure to personnel working near the following bodies of water:

Reactor vessel/internals indexing fixture	40,000 gal
Refueling canal and spent fuel pool	300,000 gal

The different processing alternatives that were evaluated were based on continuous flow systems rather than batch-type feed-and-bleed operations.

Since the DWCS will treat two separate bodies of water, it has been divided into two distinct subsystems. One subsystem will treat the water in the reactor vessel and will be designated the vesssel/IIF subsystem. The other system will process the water in the refueling canal and the spent fuel pool, and will be called the canal/pool subsystem.

DEFUELING WATER SOUCE TERMS

The selection of water processing equipment required to maintain water clarity and dose rates within acceptable limits will necessarily consider the quantities of fine particulate debris and soluble fission products currently contained within the reactor coolant system. These substances are the primary contaminants that the DWCS will be required to control. The rate at which fine particulates and fission products (particularly Cs-137) are released to the reactor vessel/IIF will determine the processing flow rates required to maintain water quality.

Unit operations that will be used to maintain water quality will consist of filtration and ion-exchange equipment. Filters will be used to remove particulate debris and maintain water clarity while soluble fission products are removed by ion-exchange in order to maintain dose rates above the water ALARA. The defueling water source term used to size these unit operations has therefore been based on a water clarity source term and a water radioactivity source term.

Solids Loadings Affecting Water Clarity

During defueling, it will be necessary to maintain water clarity at 1 NTU to ensure adequate visibility in either body of water. The major inhibitor to clarity will be the large quantity of fine debris in the reactor core. As the defueling techniques employ vacuuming and picking, some of the fine solids will be suspended throughout the defueling water.

It is therefore necessary to design filtration systems with sufficient flow capacity and micron rating to maintain these conditions during relatively quiescent periods, or to be able to return the system to these conditions in a reasonable amount of time after pikes of suspended solids occur.

Table I shows the effects of various available operating schemes to reduce the turbidity of this water. Three schemes are demonstrated; vacuuming alone (a vacuum to a "knock-out" canister to a filter canister) at 100 gpm; filtering through a DWCS filter at 400 gpm; and a combination of vacuuming and filtering (total of 500 gpm).

TABLE I

TIMES REQUIRED TO REDUCE TURBIDITY TO ACCEPTABLE LEVELS AFTER VARIOUS SOLIDS LOADINGS*

	TIME (hrs)		
SUSPENDED SOLIDS (ppm)	NO DWCS 100 gpm	DWCS 400 gpm	DWCS & VACUUM 500 gpm
91,427	76	19	15
45,713	72	18	14
9,100	61	15	12
4,600	56	14	11
900	46	11	9
90	30	7	6
9	15	4	3

* From calculations

Figure 2 shows the effect of no filtering (based on actual RCS data) and allowing the solids to settle out. Plenum removal is predicted to increase the turbidity to a minimum of 8 NTUs. This would result in a delay of 15-1/2 weeks before the turbidity reaches acceptable levels (of less than 1 NTU) if no processing were employed.

Radioactivity Source Terms

The two major sources of defueling water radiation exposure to defueling personnel will be Cs-137 and Sb-125. The DWCS maintains the dose contribution from the water at 10-20 mr/hr (or less) or returns it to this range as quickly as possible should it exceed 20 mr/hr.

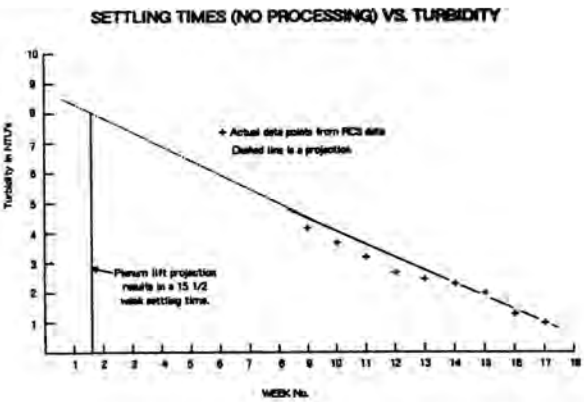

Fig. 2. Settling Times (No Processing) vs. Turbidity.

For the purpose of predicting Cs-137 loadings on zeolite ion-exchange media, a Cs-137 appearance rate scenario has been selected. It was assumed that Cs-137 will be generated at the rate of 2 Ci per day with a 35 Ci spike occurring every 20th operating day. (It must be clearly understood that this source term has been selected essentially as an accounting tool to aid in the selection and sizing of ion-exchange equipment. It does not imply that spikes of 35 Ci are the only spikes possible or that they will occur at all. Spikes of higher or lower sizes are certainly possible, but they are impossible to accurately predict.)

The steady-state value of 2 Ci per day is based on the Cs-137 appearance rate that has been observed in recent years. It is anticipated that this base rate will continue to occur during defueling with occasional spikes resulting from cutting and grinding operations.

To maintain a 0.002 μCi/ml* concentration in the reactor vessel/IIF with a steady-state generation rate of 2 Ci per day, a continuous flow rate of 20 gpm is required.

However, as a dry canal will exist between the vessel/IIF and the canal/pool, the canal/pool will not see continuous increases in radioactivity. Rather, spikes from carried particulates or leaking canisters or process lines will be the mode for increases in Cs-137 and Sb-125 in the canal/pool

* Necessary for radiation control

system. Ion exchange will be required, however, whenever a spike occurs in any body of water.

In addition to the capability to maintain the desired Cs-137 concentration of 0.02 μCi/ml during steady-state operation, the ion-exchange system must also be sized to allow the system to recover from spikes in radioactivity. For this reason, a maximum flow rate of 60 gpm has been chosen for the vessel/barrier subsystem, while a maximum flow rate of 30 gpm has been chosen for the canal/pool subsystem.

SYSTEM DESCRIPTION & EQUIPMENT SELECTION

Based on the information presented, a processing concept and the required design basis filtration and ion-exchange system flow rates have been established.

It is recommended that one filtration and ion-exchange subsystem be used to treat the water in the reactor vessel/IIF and that an additional, separate filtration and ion-exchange subsystem be used for the deep end of the refueling canal and spent fuel pool "A" (the canal/pool subsystem). This processing concept is presented on Fig. 3.

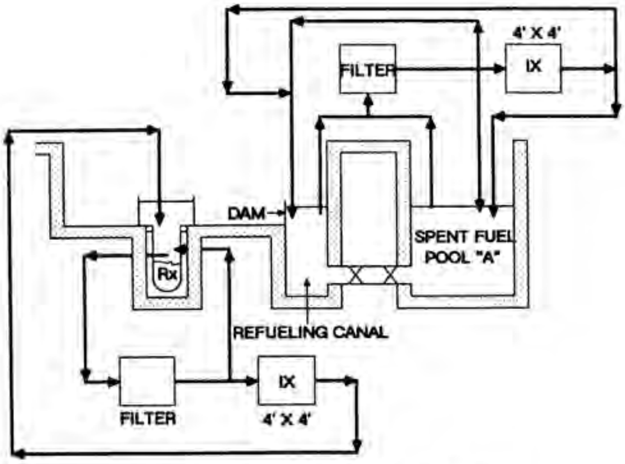

Fig. 3. DWCS Processing Concept.

REACTOR VESSEL/IIF SUBSYSTEM

The reactor vessel is the primary source of both particulate and radioactive contamination for water used as shielding in TMI-2. As can be seen on Fig. 3, water from the reactor vessel/IIF is first filtered to remove particulates with a portion of the filter effluent feeding an ion exchanger. Filtration system Clarified effluent that does not enter the ion-exchange system will be returned to the reactor vessel. Effluent from the ion exchanger will be returned to the IIF.

Reactor Vessel/IIF Filtration System

The reactor vessel/IIF filtration system is a 400 gpm system that may have to remove up to 30,500 pounds of fine fuel debris of 40 microns or less. This debris must ultimately be disposed of in a spent fuel canister, which requires that the filter media chosen be compatible with placement into these canisters.

Given the special nature of the fuel debris from both a criticality and a shielding point of view, no existing plant filtering system was considered for use in the reactor vessel/IIF subsystem. Unit operations such as hydrocyclones and centrifuges have been ruled out because the solids collected in these systems would still require another intermediate operation to transfer the retained solids to spent fuel canisters. Therefore, a means of placing a filtering system directly into a spent fuel canister was investigated to preclude the need for any other transfer equipment.

Sintered metal type filters were focussed upon early due to their 1) structural integrity, 2) backbump or backwash capability, and 3) expected performance. Early test results demonstrated the suitability of this medium as a filter element for the DWCS.

Further investigations revealed that pleated-sintered metal filters were preferable to tubular sintered metal because the pleated form allows for a higher surface-area-to-volume ratio than do tubular forms and because the flow would be similar to paper filters commonly in use (i.e., outside-to-inside), resulting in higher capture volume within a canister. Additionally, because of the larger surface area,the pleated filters load to the desired capacity without back bumping, resulting in a much simpler system design.

The equipment selected for this application is a filter consisting of a bundle of pleated-sintered metal filter elements placed directly within a spent fuel canister (see Fig. 4). The canister will be placed under water in the refueling canal. Water will be pumped to the outside of the pleated sintered metal tubes until either the filter canister is full or the differential pressure across the filter element reaches a preset limit. Sufficient time may then be allowed for the solids to settle at the bottom of the canister. After settling is complete, filtering operations may resume.

Four canisters will be arranged in parallel to develop the required 400 gpm flow rate. When the canisters are full, they will be dewatered and disposed of in the same way as TMI-2 fuel debris.

Reactor Vessel/IIF Ion Exchange System

The RV/IIF ion-exchange system will be required to operate at a minimum continuous rate of 20 gpm in order to offset the anticipated 2 Ci per day appearance rate of Cs-137. To be able to return the RV/IIF to acceptable Cs-137 concentration within a reasonable time, the ion-exchange system must be capable of increasing its continuous flow rate to 60 gpm in the event of spikes in Cs-137 activity above the nominal 2 Ci per day appearance rate.

Because no existing plant ion-exchange system is capable of these flow rates, a new processing system was devised utilizing a 4'x4' high integrity container (HIC) filled with zeolytes as the demineralizer.

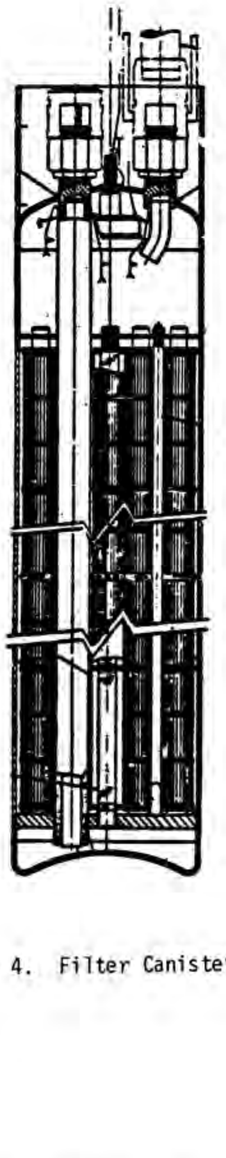

Fig. 4. Filter Canister.

Deep End of the Refueling Canal/Spent Fuel Pool "A" Subsystem

As with the reactor vessel/IIF processing subsystem, the processing subsystem for the deep end of the canal and "A" pool uses a filtering system in series with an ion-exchange system.

The major source of contaminants in the deep end of the refueling canal and spent fuel pool "A" will be: a) contaminants that adhere to the outside of the filter canister during transfer operations; and b) contaminants transferred from the vessel due to filter line breaks or filter connection leaks. While the canal and pool should not experience the same high levels of contamination as the reactor vessel/IIF, the volumes of water are much larger. A larger volume of water requires a longer processing time to recover from a given spike in Cs-137 or suspended solids at a given flowrate.

When processing is needed, filtration and ion exchange (DWCS ion exchangers) will be used to return the Cs-137 concentration to acceptable levels. The Submerged Demineralizer System (SDS) can be used as a parallel system to remove slight contamination.

The normal operating mode for the canal/pool subsystem will be to take suction water from the refueling canal and return water to spent fuel pool "A". The two bodies of water will be connected via the two fuel transfer tubes, which will ensure that the same level of water is maintained in the canal and pool. It will, however, be necessary to be able to take water from and return water to either body of water. This will ensure that either the canal or pool can be treated exclusively should the need arise.

Deep End of the Refueling Canal/Spent Fuel Pool "A" Filtration System

The canal/pool filtration system is a 400 gpm system that will be used for controlling turbidity in the refueling canal and spent fuel pool "A".

The primary source of contamination to the canal and pool will be due to leakage from the reactor vessel from filtration lines. This leakage could contain substantial amounts of fine fuel debris, which would require that the filter media used in the canal/pool subsystem be disposed of in the same type of spent fuel canister as used in the RV/IIF filtration system.

Due to the ease of fabrication and predictable recovery times, the same system was employed as the canal/pool filtration system as the vessel/IIF system.

Refueling Canal/Spent Fuel Pool "A" Ion-Exchange System

The canal deep end/"A" pool ion-exchange system will be required to operate at 30 gpm to control spikes in soluble activity, particularly Cs-137. The major source of Cs-137 activity will be due to one of two major sources: external contamination on the fuel canisters; or a fuel canister leak or drop. The canal/pool ion-exchange system will only need to operate when canal or pool water exceeds the desired Cs-137 concentration of 0.01 μCi/ml. This means that the canal/pool ion-exchange system should only have to operate intermittently, in response to transient conditions. This system parallels the vessel/IIF ion-exchange system.

Additional advantages of utilizing a similar demineralizer configuration not presented previously are:

1. During periods when the pool/canal system requires clean-up by both filtration and ion-exchange, by using a second 4'x4' HIC

ion exchanger, the flow rate can be increased to 60 gpm (leaving 30 gpm for vessel/IIF cleanup).

2. Ion-exchange may not be required for several months after defueling commences, allowing reduced source terms due to the reduced amount of fuel present.

3. If no filter line breaks occur, this ion exchange system will serve only as an emergency use system.

Definitions:

EPICOR II - an organic ion-exchange system designed to process the Auxiliary Building accident water, later used to polish the Submerged Demineralizer system effluent.

SUBMERGED DEMINERALIZER SYSTEM (SDS) an ion-exchange system that utilizes zeolite resins to remove radioactive Cesium and Strontium from the highly radioactive water.