RADWASTE PROCESSING AT THE ADVANCED TEST REACTOR FACILITY

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ABSTRACT

The Advanced Test Reactor (ATR) is a 250-MW (thermal) water cooled reactor located at the Idaho National Engineering Laboratory. The reactor is used primarily to test materials in a radiation environment for defense related programs. Operation of this facility includes processing of radioactive waste streams in solid, liquid, and gaseous forms. Since the materials tested in reactor experiment facilities are sometimes destructively tested, the radwaste process capabilities for experimental facilities must be capable of handling a relatively wide range of contamination levels in the waste streams.

Modifications to the original plant (designed in 1967) have been concerned with reducing the volume and activity level of liquid waste. Included are modular filtration and ion-exchange units that were developed to convert canal cleanup from an open loop flush to a closed loop recirculation system. Another plant improvement involved an ion-exchange treatment system that reduces the level of radiological contamination in the low level waste water. A system to evaporate the water from high level waste is presently in development, and is also discussed.

PROGRAM HISTORY

The ATR is located at the Test Reactors Area (TRA) which includes the Materials Test Reactor and the Engineering Test Reactor, both of which are decommissioned. TRA liquid waste consists primarily of effluents from the Advanced Test Reactor (ATR). Other effluent sources include several low-power nuclear facilities and radiochemistry laboratories.

A three-phase program formulated to eliminate radioactive liquid waste at the TRA consists of the following projects:

Phase I

- drain segregation
- storage canal water recycle
- warm waste water ion exchange

Phase II

- additional warm waste water ion exchange
- primary cooling water recycle
- hot liquid waste evaporation

Phase III

- polishing equipment for primary cooling water
- additional storage capacity for recycled water

As a result of efforts initiated by the Phase I Project, the volume of liquid waste was reduced by a factor of four, and the activity by a factor of 14. Construction is complete on the Phase I project. The Phase II Project, presently 90% complete continues the treatment of these wastes and has further reduced the liquid waste volume by a factor of four, and activity by a factor of six.

The Phase III Project will eliminate all radioactive liquid waste from TRA.

The first priority in the program was to reduce the volume of the waste water. This was accomplished primarily by three projects: drain segregation, fuel storage canal water recycle, and primary coolant recycle. A brief explanation of each project follows.

METHODS OF VOLUME REDUCTION

Drain Segregation

All drains were examined for sources of noncontaminated water. The sources of noncontaminated water were rerouted from the ATR warm waste tank to cooling tower makeup or sanitary sewer drains. Contaminated sample lines were rerouted from the warm waste tank back to the primary system. New piping was also installed to separate high and low level contaminated wastes to allow routing to special tanks for evaporation or to treatment systems. Sump pumps were installed in several areas to replace water to water eductors.

Fuel Storage Canal Recycle

The fuel storage canal was being purged at the rate of 60 to 70 gpm to provide cooling, algae control, and radioactivity control. The ATR canal water recycle system removes fuel element decay heat from the canal water and controls microorganism populations in the water. The recycle system consists of recirculation pumps, a heat exchanger, an ultraviolet sterilizer, piping, valves, and associated instrumentation. The two pumps are centrifugal pumps each rated for 650 gpm at 200 ft TDH. The heat exchanger is a water to water shell and tube type which utilizes cooling tower makeup water to cool the canal water. The design heat removal capacity is 3.76×10^6 Btu/h. The ultraviolet sterilizer is located downstream of the heat exchanger and is rated at 315 gpm. The sterilizer consists of two separate cylinders each containing 12 ultraviolet lamps. All water passing through the sterilizer exits free of living microorganisms.

Primary Coolant Recycle

The ATR utilizes a gland seal system to minimize leakage from the primary system. This system maintains a buffer of pressurized nonradioactive water outside all primary system penetrations such as control rod seals, pump seals, and experimental penetration seals. In order to maintain a constant primary system volume, the "in-leakage" is drained from the primary system through demineralizers to a collection tank which in turn, feeds the gland seal pumps. The large majority of the seal water is therefore recycled rather than replenished with fresh water. The recycled water is deionized and degassed at the collection tank so that the only contamination remaining in the recycled water is a small quantity of tritium.

METHODS OF ACTIVITY REDUCTION

In addition to the volume reduction several methods were undertaken to reduce the activity of the remaining liquid effluent. The reduction was accomplished primarily by ion exchange. The first set of ion-exchange beds was incorporated in the canal cleanup system. The next step was to place mixed ion-exchange beds on the warm waste outlet lines. Finally, the liquid waste which was too radioactive or too high in dissolved solids for ion-exchange treatment was treated by means of evaporation. A brief discussion of each project follows.

Canal Ion-Exchange Modules

The ion-exchange system consists of two ion-exchange units installed directly in the ATR storage canal. Each unit is identical and is designed for a minimum ion exchange resin lifetime of one year. The units are installed at opposite ends of the canal.

Each ion exchange unit consists of a disposable concrete module containing ion-exchange resin, a submersible pump, a filter system, a flow indicator, a canal water surface skimmer, and associated flexible hose for an inlet, discharge, and sample line. Each unit is designed to operate continuously until the resin is depleted, the filters are loaded, or until planned maintenance is required. A flow diagram of the module is shown in Fig. 1.

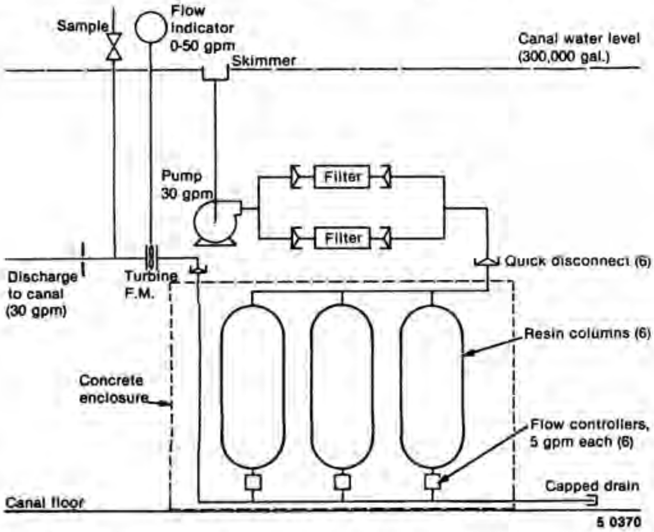

Fig. 1. Canal Module Flow Diagram

Each disposable concrete module is 66 in. long, 50 in. wide, 60 in. high, and weighs ∿8.5 tons. Four stainless steel lifting ears are used in lifting a module. Since each disposable module will contain contaminated ion-exchange resin, it was necessary to analyze the adequacy of the concrete shielding which surrounds the resin. The average thickness of the concrete shielding is ∿8 in. The shielding analysis yielded an exposure rate of 36 mR/h at 1 in. from the module. Each concrete module is painted with one coat of epoxy primer and two coats of epoxy protective coating. The protective coating prevents canal water from leaching substances from the concrete and also facilitates decontamination when the module is depleted and ready for shipment to the Radioactive Waste Management Complex (RWMC). There are only three penetrations in each module. Each penetration is plugged before a depleted module is shipped to the RWMC.

Standard submersible well pumps are used to continuously circulate canal water through the ion-exchange modules and through filter systems. Each module has a pump housed in an aluminum pipe sleeve which is part of a pump-filter assembly. The pump-filter assembly is mounted on top of the ion-exchange module after it is positioned in the canal. The aluminum pipe sleeve serves to direct inlet flow over the pump motor and into the pump inlet. The sleeve also provides protection for the pump and its motor. A flanged connection on one end of the sleeve makes its removal possible for pump-motor inspection or maintenance. Each nine-stage pump is rated for a TDH of ∿140 ft at a flow rate of 30 gpm. Constant flow control valves in the ion-exchange modules limit the output of the pump to 30 gpm.

Immediately downstream of each pump discharge, the canal water is filtered with 3-μ disposable cellulose filters. Four filter cartridges are contained in two polypropylene filter housings for the pump-filter assembly. The 1-1/2-in. pump discharge is split into two parallel streams to serve the two filter housings. Low cost filter cartridges and housings make it possible to dispose of both without requiring any filter cartridge handling. Quick disconnects manipulated by canal or reactor handling tools make filter housing changes possible without requiring any movement of the installed pump-filter assemblies. Downstream of the filter assembly is the ion-exchange module. Each module contains six ion-exchange columns which have strainers to assure containment of the resin. The 3-μ disposable filter assemblies assure that the inaccessible strainers will not be plugged with canal water impurities. There is a fixed-flow control valve at the outlet of each ion-exchange column that regulates column flow to 5 gpm.

After canal water has circulated through the ion-exchange module, it is passed through a turbine flowmeter before being discharged back into the canal. The flowmeter is a part of the pump-filter assembly and is ∿13 ft below the canal water surface. The turbine flowmeter is rated for a flow range of 14 to 140 gpm. An instrumentation lead is routed from each flowmeter to a 0- to 50-gpm flow indicator mounted on the parapet. The flow indicator makes it possible to monitor the performance of each ion-exchange unit and also serves as a means of determining when the filter assemblies should be changed. Each ion-exchange unit is equipped with a sample line to allow assessment of the ion-exchange performance. Flexible tubing is routed from each unit to a sample valve located above the canal water surface but within the parapet. A comparison of the bulk canal water with the water obtained from the sample line makes it possible to determine when the resin in an ion-exchange module is depleted.

Warm Waste Treatment Ion Exchangers

To remove radioactivity, water collected in the ATR warm waste catch tank is pumped to a shielded cubicle at the southwest corner of the ATR reactor building where it passes through a strainer and a mixed bed ion exchanger. Suspended solids removed by the strainer are periodically blown down and retained in a shielded catch cask for later controlled solid waste disposal. Dissolved solids trapped on the ion exchanger resins are stripped during regeneration and routed to the building hot waste catch tank for subsequent controlled disposal. A flow diagram of the warm waste treatment system is shown in Fig. 2.

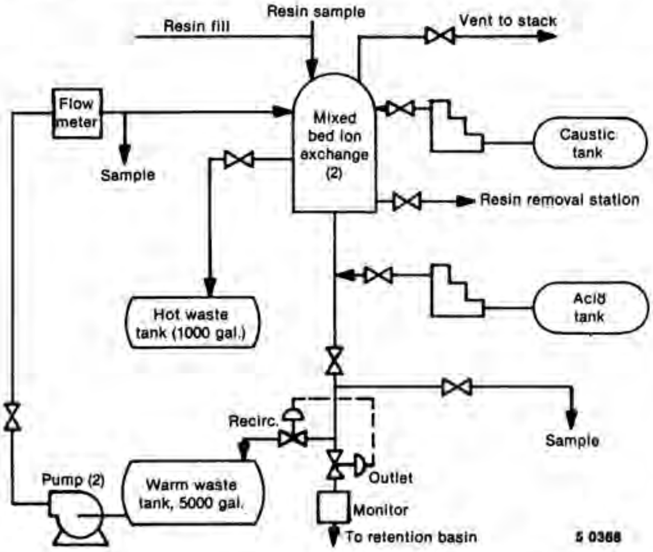

Fig. 2. Warm Waste Treatment Facility Flow Diagram.

Provision has been made for removal of spent or degraded resins from the ion exchangers by sluicing them to an outside resin disposal pad where they are received by a shielded truck-mounted tank.

One of two waste tank mounted pumps provides a normal system flow of 100 gpm. If required, a booster pump in the cubicle can be used, in conjunction with the two tank pumps, to provide higher flow (up to 200 gpm) for short intervals.

A cubicle exhaust system draws air from the back of the cubicle to assure air flow will be from uncontaminated to contaminated areas. Air is discharged to the building exhaust system.

The ion exchangers are mixed bed (anion and cation resins mixed together in the same bed) designed for in-tank regeneration. The tanks are designed to contain 50 ft^3 of resin (2/3 anion and 1/3 cation) and still provide 100% freeboard above the top of the bed for regeneration. The tanks are constructed of carbon steel and lined with a 3/16-in. thick coating of natural rubber. Stainless steel distribution headers are used for the normal inlet at the top, for the caustic inlet just above the bed, for the interface drain at the resin interface, and for the outlet immediately above the flat bottom of the tank. The resins are separated (classified) for regeneration by a backwash or upflow. Anion resins being lighter settle at the top of the resin bed when backwash is stopped. The proportions of anion and cation resins, stated above, then determine the level of the interface between the resins. Three viewports are provided in the tank wall. The first is located below the inlet distribution header near the top of the tank and allows checking resin level. The second viewport is located at, and above, the resin interface to allow viewing the anion resin and the interface. The third viewport is located below the resin interface and allows viewing the cation resin.

The ion-exchange tanks are sized to provide a bed cross-sectional area of 12.5 ft^2 which at 75 gpm gives a flow density of 6 gpm/ft^2 and at 150 gpm, 12 gpm/ft^2. Six gpm/ft^2 is well above the minimum required for good bed operation; 12 gpm/ft^2 is near, but not in, the range where bed packing is likely to occur.

A valve nest assembly is designed as a skid mounted unit separate from the ion-exchange beds and installed in the piping corridor portion of the cubicle. The valve nest assembly is positioned in front of a shield wall thus shielding the valve nest from radiation emanating from the ion-exchange beds. Access is required for operation in addition to occasional access for maintenance. In the event of loss of instrument air or control power, valve design and system controls will close all peripheral valves except the discharge valve. This isolates the ion-exchange system from all inlet and regeneration flows.

The inlet warm waste strainers are 2-1/2 in. Y-type strainers fabricated of stainless steel, and are one size larger than the line pipe to keep pressure losses down. The strainer screen assemblies are cylindrical with 60-mesh screen made of 0.0065-in. diameter, 304 or 316 SST wire. The 60-mesh screen is backed on the outside with a heavier backing screen. The backing screen is 37% open area and capable of withstanding up to 100 psid. The strainers are flanged at the bottom of the screen assemblies and have a 1-in. threaded outlet in the flange for blowdown flow. The strainer, when clean, should exhibit a pressure drop of 2.00 psi at 150 gpm. A 50% blockage of the screen will approximately double the pressure drop.

The resin disposal system is designed to slurry spent or damaged resin from the ion-exchange tank(s) to a truck-mounted 1000-gal disposable tank located adjacent to the resin transfer pad outside the building. Hard-piping buried below frost line is used to carry the slurry from the cubicle to the resin transfer pad. Standpipes and quick connects are used at the transfer pad for hose connections to the disposable tank.

The disposable tank when prepared to receive the resin slurry is mounted horizontally on a truck and contains a 1-ft thick anthrafilt bed to filter out the resins. A screened wellpoint under the anthrafilt and a 1-in. drain line allow the water to be drained off the tank. Resin is slurried from the ion-exchange tank(s) by demineralized water added to the tank(s) from the valve nest area. Up to 53 gpm can be introduced through the ion-exchange tank normal outlet and/or 60 gpm through the ion-exchange tank normal inlet. Pipeline velocity at the 53 gpm flow rate is just over 5 fps which exceeds the 3 fps minimum for resin slurries.

Additional hardware included in the system are the chemical regeneration tanks, pumps, and associated hardware all of which are standard for a mixed bed ion-exchange system.

Radwaste Evaporation

The radwaste evaporator system is a modular type system to which additional units may be added. The unit presently in development is designed to process 150 gal of waste water containing 4% dissolved solids per day. Figure 3 is a flow diagram of the radwaste evaporation system, which functions as follows:

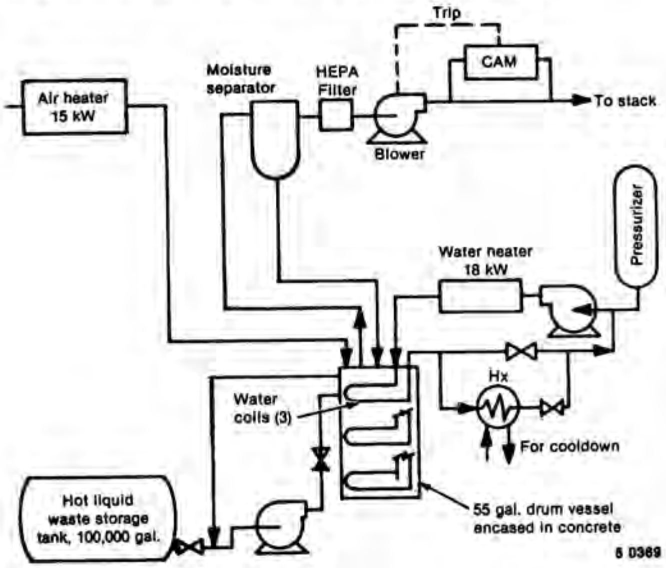

Fig. 3. Radwaste Evaporator Flow Diagram.

An evaporator vessel is filled with waste water which is evaporated to dryness, leaving the dried salts in the vessel. The vessel is refilled with hot waste then evaporated to dryness again. This process is repeated until the vessel is full of dried salts. At this time the process lines are disconnected and all openings are sealed with concrete and other appropriate sealants. The vessel is then sent to the burial grounds for disposal. Except for the initial connecting and final disconnecting of the process lines and final sealing, the system is designed to operate autonomously without operator intervention.

The system consists of an evaporator vessel, a waste transfer system, a hot water circulation system, and a hot air system.

The evaporator vessel consists of a 55-gal drum surrounded by 1 ft of concrete for shielding. Permanently located inside the vessel are three sets of heating coils that are part of the hot water circulation system, described later.

The waste transfer system consists of a 15-gpm waste transfer pump which takes suction from a 100,000-gal waste storage tank and discharges into the evaporator vessel. A flow totalizer located on this line records the total amount of waste processed. There is an overflow from the vessel with a flow switch located in it. The transfer pump is automatically started by a low moisture switch located in the hot air system. Pump operation is terminated by a high level switch located in the evaporator vessel or, in the event of a failure, by the flow switch.

The hot water circulation system is a closed loop heating system that is used to boil the waste water in the evaporator vessel. The system consists of a hot water circulation pump, a hot water heater, three independent banks of heating coils located inside the evaporator vessel, a hot water pressurizer, a hot water heat exchanger, a makeup pump, a minimum flow regulator, interconnecting piping and valves, and instrumentation and controls. The pump circulates the water through the heater which heats it to ∿350°F, through the heating coils where the heat is transferred to the hot waste, through the flow control valve which varies the flow rate in accordance with moisture requirements in the hot air system, then back to the pump. The pressurizer is a bladder-type accumulator that is pressurized by the plant air system to ∿125 psig. Upon completion of a run (when the vessel is full of dried salts), the heat exchanger is valved in and the system cooled down. The three coils in the vessel are individually controlled by solenoid valves for coils 1, 2, and 3, respectively. Coil 1 is at the bottom of the vessel. Upon initial startup of a run (new vessel) only coil 1 is in operation. As the run progresses, this coil may become covered with dried salts and lose its heat transfer capability. When this happens (as determined by the length of time it takes from refill of the vessel to full boiling), coil 2 is turned on. As the run progresses further, this coil may also become covered with dried salts and lose its heat transfer capability. When this happens coil 3 is turned on. Coil 3 is near the top of the vessel so that when it becomes covered with dried salts, the vessel is full and the run is terminated. This event is annunciated.

A hot air system carries away the moisture boiled off by the hot water circulation system and discharges it to the stack. The hot air system draws 200 cfm of air from outside, through the air heater where it is heated to 200°F, through the evaporator vessel where the moisture is picked up, through a moisture separator where any liquid carryover is removed, through a HEPA filter to remove any solids carryover, through an exhaust blower, then to the suction of the existing waste tank exhaust fan which discharges to the stack. A moisture transmitter is located in the line between the HEPA filter and the exhaust blower. This transmitter is connected to a moisture controller which maintains a constant relative humidity of 20% in the air line by varying the hot water circulation rate through the heating coils. An inspection window is located in the air line from the vessel to the moisture separator to allow visual inspection inside the vessel without having to shut down the plant and open it up.

SUMMARY

In summary, the methods of volume and activity reduction of the ATR waste water have reduced the volume of waste water by a factor of 16 and reduced the activity by a factor of 84. Future plans include a recycle system which would reduce the liquid waste output to zero.