

Westinghouse Technology Systems Manual

Section 15.1

Liquid Radioactive Waste Processing Systems

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15.1 LIQUID RADIOACTIVE WASTE PROCESSING SYSTEMS

Learning Objectives:

1. Explain why liquid radioactive waste is separated into reactor-grade and nonreactor-grade wastes.
2. List three inputs to the reactor-grade waste subsystem.
3. List three categories of nonreactor-grade wastes.
4. Briefly explain three liquid radioactive waste processing methods.
5. Define the term “decontamination factor” (DF).

15.1.1 Introduction

The liquid radioactive waste (LRW) system collects, stores, and processes radioactive or potentially radioactive waste for recycling to the reactor coolant system (RCS) or for releasing to the environment. This system (Figure 15.1-1) begins at the interfaces with the reactor coolant pressure boundary, and the interface valve(s) in lines from other systems, or at those sumps and floor drains provided for liquid waste with potential of containing radioactive material. It terminates at the point of controlled discharge to the environment, at the point of interface with the waste solidification system, and at the point of recycle back to storage for reuse.

Provisions are made to sample and analyze these liquids. Based on laboratory analysis, these wastes are either recycled for reuse, released under controlled conditions via the service water system, retained for further processing, or transferred to the solid waste system (Section 15.2) for solidification. The amount of liquid waste that enters the LRW system is limited so that relatively small quantities of generally low level wastes are processed. To limit the input into the LRW system, most of the water discharged from the RCS is processed by the boron recycle system (Section 4.1).

The liquids that are not processed by the boron recycle system enter the LRW system, which is arranged to recycle as much water entering the system as practical. This is accomplished by segregation of equipment drains and waste streams to prevent the intermixing of the liquid wastes. The LRW system consists of two main subsystems which process reactor grade and nonreactor-grade effluents. In addition, the system is capable of handling drains which may contain reagents or chemicals and has the capability for handling spent demineralizer resins.

The LRW system is designed so that at least two valves must be manually opened to permit discharge of liquids to the environment. One of these valves is normally locked closed. The discharge line also has a control valve that will automatically trip closed on high effluent activity level.

The LRW system is constructed of materials that meet the requirements of the system and applicable codes. In addition, all parts or components that may come in contact with borated water are fabricated of or are clad with stainless steel. Equipment and components within the LRW system are located and arranged to reduce radiation exposure to plant personnel during operation and maintenance. All tanks and process equipment are shielded so that normally occupied areas are in radiation fields of less than 2.5 mrem/hr. Process equipment is located and arranged to provide space for removal and replacement of components and the equipment itself. Process subsystems are arranged to reduce the length of piping runs. Process equipment, such as filters, ion exchangers and evaporators, are usually located in individual cells. Equipment is designed to facilitate rapid disconnection for removal, replacement and ease of in-place maintenance. Table 15.1-1 lists the liquid waste systems at selected facilities.

15.1.2 System Description

15.1.2.1 Separation of Reactor-Grade and Nonreactor-Grade Liquids

Liquid radioactive waste is collected in various tanks. The inputs to these tanks come from various drains and are separated and treated as reactor-grade and nonreactor-grade liquids.

Reactor-grade liquids are liquids whose tritium concentration is 10% or more of primary coolant tritium activity and can be processed for reuse as demineralized water or concentrated boric acid solution.

Nonreactor-grade liquids are liquids having a tritium concentration of less than 10% of that of the primary coolant and, due to their composition, cannot be processed for reuse.

15.1.2.2 Reactor-Grade Water (Recycle)

The recycle section is provided to process reactor-grade water which enters the LRW system. Deaerated, tritiated RCS water collected directly in the reactor coolant drain tank, Figure 15.1-2, may be routed directly to the boron recycle holdup tanks for processing in the boron recycle system or routed to the miscellaneous waste tank. Aerated and tritiated water is collected in the miscellaneous waste tank, Figure 15.1-3.

The systems used to process miscellaneous waste include ion exchange, evaporation, or equivalent processes. Evaporation is selected as a primary processing method, as it is very efficient at reducing the amount of contaminated water with ionic and particulate contaminants. Various processing methods are discussed in detail in section 15.1.3 in this chapter. The basic composition of the liquid collected in the miscellaneous waste tank is boric acid and water with some radioactivity. Liquid collected in this tank is evaporated to remove radioisotopes, boron, and air from the water so that it may be reused in the RCS.

Evaporator bottoms are normally drummed (in the solid radioactive waste system) unless found acceptable for boric acid recycle. The condensate leaving the miscellaneous waste condensate polishing demineralizer enters the monitor tank. When a sufficient quantity of water has collected in the monitor tank, it is sampled to determine if it is suitable for recycle (to the primary water storage tank for reuse), discharge, or if it must be reprocessed in the LRW system.

15.1.2.3 Nonreactor-Grade Water (Waste)

This waste category is designed to collect and process nonreactor-grade liquid wastes. These include chemical wastes, detergent wastes, and secondary system wastes. The inputs to these tanks are gravity drains. Each of these collection points has a pump to recirculate the contents of the collection tank for sampling and for transferring the liquid for processing. After processing, the liquid is transferred to a monitor tank. The monitor tank has a pump to recirculate the contents of the monitor tank for sampling. Depending on the results of the sample, the monitor tank transfers the contents for discharge, recycle for reuse, or reprocessing.

Chemical Waste

Input sources include radiochemistry laboratory drains, chemical cleaning waste, decontamination waste, and other liquid radioactive wastes which contain high concentrations of chemicals. The chemical waste may be treated separately, as shown in Figure 15.1-4, and transferred to the miscellaneous waste system, or transferred directly to the solid waste system.

Detergent Waste

Input sources, Figure 15.1-5, include laundry, personnel decontamination, and other liquid radioactive wastes containing detergents and soaps. The detergent waste may be treated separately or processed directly in the solid waste system. This system should be segregated from other waste collection systems to reduce operational problems with processing equipment.

Secondary System Waste

Input sources, Figure 15.1-6, include steam generator blowdown, turbine building drains, and ion exchange spent regenerant solutions. The secondary system wastes may be treated separately, or in the event of primary-to-secondary leakage, the turbine building drains and steam generator blowdown may be treated in the miscellaneous waste system. The ion exchanger spent regenerant solutions may be treated in the chemical waste system.

15.1.3 Processing Methods

“Decontamination factor” is a term used to describe the efficiency of a processing method removing contaminants from a process stream. The decontamination factor (DF) is the ratio of the initial amount of activity in a stream to the final amount of activity in a stream following the treatment by a given process. Therefore, if a given

process has a DF of 2, the final activity level is one half of the original activity. Decontamination factors for liquid waste processing are obtained by the selection and combination of a number of unit operations. Currently, the principal unit operations for treating liquid radioactive waste are filtration, ion exchange, evaporation and reverse osmosis.

15.1.3.1 Filtration

Filtration is defined as the separation of undissolved particulate, suspended solids from a fluid mixture by passage of most of the fluid through a septum or membrane that retains the solids on or within itself.

Cartridge-Type Filter

Cartridge filters, Figure 15.1-7, are designed with replaceable elements which are discarded when contaminated. These elements are usually constructed of pressed paper, matted fibers, or porcelain materials. In general, these types of elements are used in low pressure, low temperature systems.

Precoat-Type Filter

Precoat filters, Figure 15.1-8, use elements designed as retainers to prevent a precoat material from being flushed downstream. The actual filtering of system contamination is accomplished by the precoat material. This type of filter is limited by temperature, flow, and pressure extremes. In addition, the large quantities of precoat material which must be disposed of can present significant problems in terms of handling and disposal.

Filters will remove radioactive particulates but have no effect on ionic removal. Therefore, filters are normally given a decontamination factor of 1.

15.1.3.2 Ion Exchange

An ion exchanger (demineralizer) is a device that uses a polyelectrolyte to exchange mobile ions of equal charge from the surrounding solution. The polyelectrolyte is essentially a plastic bead which has ions weakly attached to it; typically used is HOH type resin. When a liquid is passed across this bead, it will readily exchange the ions on the bead with ions of the same charge in the liquid. There are basically two types of resins, cation and anion resins. The cation resin has a positive ion attached in the hydrogen (the H part of HOH resin) form. The anion resin has a negative ion attached in the hydroxide (the OH part of HOH resin) form. Generally, ion exchangers use a combination of these resins and are called mixed-bed ion exchangers or demineralizers.

De-ionization with mixed bed ion exchangers is capable of producing water of exceptional purity. On occasion, the effectiveness of an ion exchanger material may be impaired due to the accumulation of insoluble materials, such as oil or particulates, on the surface and the interior of the ion exchanger. It is best to avoid or minimize this fouling by the use of suitable pretreatment filtration.

The decontamination factor of ion exchangers varies from 1 to 100. This depends upon the conductivity of the solution, the location of the ion exchanger in the process stream, and if the ion exchanger is a single unit or in series with another ion exchanger.

15.1.3.3 Evaporation

Evaporation is the process by which a solution or slurry is concentrated via boiling the solvent. This process leaves most of the solids behind, and the condensed steam is essentially pure water.

The basic operation of a waste evaporator is to receive a solution to cause boiling. This boiling causes radioactive gases to leave solution. These gases are collected and vented to the waste gas system. The steam generated due to boiling is collected, condensed, and treated as deaerated, essentially pure water, which can be recycled for reuse. The solution left behind in the evaporator bottoms is called the concentrate. The concentrate generally has a high concentration of radioactive material, and this solution can be recycled for further processing, or more often, it is transferred to the solid waste system for solidification.

Evaporation has a wide application in the nuclear industry for reducing waste volumes and for reducing the amount of radioactive nuclides in liquid effluents. It is usually used for radioactive wastes that require a high degree of separation and are not readily treated by low temperature operations such as filtration or ion exchange. In the design of evaporators for concentrating radioactive liquids, vapor separation is the most important factor, as decontamination of the liquid is the main objective. Volume reduction is a secondary objective, and least important is minimizing the heating costs.

Evaporators can separate water from solids very effectively, and a system decontamination factor of 10^4 to 10^5 is generally expected. However, for present-generation waste evaporators to realistically achieve this decontamination factor, the flow rate must be very low, on the order of 15 gpm or less.

15.1.3.4 Reverse Osmosis

Reverse osmosis is a process in which filtering at the molecular level removes dissolved minerals, dissolved organics and biological and colloidal matter from water.

Osmosis is the natural process whereby pure water flows through a semipermeable membrane from a dilute solution into a more concentrated solution. This process dilutes the concentrated solution. Reverse osmosis is the process by which pressure is applied to the concentrated solution thereby forcing pure water to flow in the reverse direction through the semipermeable membrane.

The result of this process is that the concentrated solution becomes more concentrated. Reverse osmosis has been found to be very effective in the treatment of detergent waste. The decontamination factor for the reverse osmosis

unit is about 30 for the processing of detergent wastes. The decontamination factor for all other liquid wastes is 10.

15.1.4 System Interrelationships

15.1.4.1 System Decontamination Factor

As discussed in Sections 15.1.2.1 through 15.1.2.4, various methods are available for the processing of LRW. Usually the processing system employs several of these in series. To determine the decontamination factor for a given process stream, the product of all the methods used in that stream is calculated.

As an example, a hypothetical system consists of an inlet filter, an evaporator, an ion exchanger, and an outlet filter. The decontamination factor for each of these methods would be: inlet filter - 1, evaporator - 10^4 , ion exchanger - 10, and outlet filter - 1.

To determine the system DF, the product of the component DFs is calculated:

$$\text{System DF} = 1 \times 10^4 \times 10 \times 1 = 10^5$$

Therefore, the DF for this hypothetical process stream is 100,000.

15.1.5 Summary

The liquid radioactive waste system is designed to collect, store, process and dispose of radioactive or potentially radioactive liquids. The liquids are collected by gravity drains and segregated into various tanks as reactor-grade and nonreactor-grade liquids. This segregation is necessary because the different grades of liquids must be processed by different methods.

There are different methods of processing these collected liquids. The processing methods include filtration, ion exchange, evaporation, and reverse osmosis. Normally, one or more of these processing units will be utilized in the process stream.

After processing, the liquid is transferred to monitor tanks. The liquid is sampled, and depending upon the results of the sample, is recycled for reuse, reprocessed, or released to the environment.

With today's emphasis on limiting discharges from the LRW system to the environment, the LRW system is designed to recycle as much liquid as possible, to limit the amount of radioactivity released to the environment, and to limit the doses received by plant personnel. Therefore, great emphasis is placed on maximizing the decontamination factors for the process stream and volume reduction. Liquid that cannot be recycled (due to high activity, chemical composition, etc.) is transferred to the solid waste system for processing. After solidification, this waste is placed in storage on site, or transported to a permanent burial facility.

**Table 15.1-1
Liquid Waste Systems and Capacities**

Plant Name	Chemical Drain	Laundry & Hot Shower	Reactor Cont. Drain	Spent Resin Storage	Waste Holdup	Waste Monitor
R.E. Ginna	375	2 @ 600	350	2 - ?	21,000	
Kewaunee	To H/U Tank	2 @ 700	350	1 - ?	24,490	
Point Beach 1 & 2	600*	2 @ 700	350	1 - ?	21,000*	
Prairie Island 1 & 2	600*	2 @ 700	350	1 - ?	24,490*	2 @ 10,000
Beaver Valley 1 & 2	?	2 @ 1,300*	350	1,400*	2 @ 5,000	
J. M. Farley 1 & 2	600	10,000*	350	2 @ 2,600*	1000	2 @ 5,000
Sharon Harris	?	2 @ 25,000*	350	2 - ?	25,000	
North Anna	?	?	?	1,100	2 @ 5,000	
H. B. Robinson	600	2 @ 600	565	300	24,000	
San Onofre	375	?	784	1 - ?	3 @ 52,000	2 @ 3,740
V. C. Summer	600	10,000	350	2,600	10,000	2 @ 5,000
Surry 1 & 2	?	?	?	2,019*	2 @ 2,390*	2 @ 3,000
Turkey Point	?	3 @ 600	350		2 @ 10,000*	2 @ 5,000
Byron 1 & 2	6,000*	4,000*	350	5,000*	?	2 @ 20,000
Braidwood	6,000*	4,000*	350	5,000*	?	
Calloway	600	10,000	350	?	10,000	2 @ 5,000
Catawba	600*	10,000	350		2 @ 5,000	2 @ 5,000
Commanche Peak	600*	10,000*	350	4,100*	10,000*	2 @ 5,000*
D. C. Cook	600*	2 @ 600*	350	300*	2 @ 25,000*	
Diablo Canyon	1,000	2 @ 1,000	400	2 @ 15,000	2 @ 15,000	
McGuire 1 & 2	600*	10,000*	350	2 @ 5,000	5,000*	2 @ 6,080

Table 15.1-1 (cont'd)
Liquid Waste Systems and Capacities

Plant Name	Chemical Drain	Laundry & Hot Shower	Reactor Cont. Drain	Spent Resin Storage	Waste Holdup	Waste Monitor
Millstone 3	To Hi Lvl Waste	To Lo Lvl Waste	350	3,200		2 @ 21,000*
Salem	600	2 @ 600*	565	300	2 @ 25,000	2 @ 25,000*
Seabrook 1 & 2			350			2 @ 25,000*
Sequoyah 1 & 2	600*	2 @ 600*	350	2,600*	24,700*	10,000*
Trojan	6,500		347	2,600		2 @ 15,322
Vogtle	600*	10,000*	350	2,600	10,000	2 @ 5,000
Wolf Creek	600	10,000	350	2,600	10,000	2 @ 5,000
Zion 1 & 2	12,500	2 @ 1,500	350	5,000	2 @ 30,000	6,000

* common to both units

**Table 15.1-2
Liquid Waste Evaporators and Miscellaneous Tanks**

Plant Name	Waste Evaporator Capacity (gpm)	Waste Evaporator Concentrate Tank	Waste Evaporator Condensate Tank	Miscellaneous Tank	Comments
R.E. Ginna			2 @ 600		Ultra-filtration as a prefilter for evaporator
Kewaunee	2 - ?		2 @ 1,000	Sump Tank 600	
Point Beach 1 & 2	1 - ?		1,000*	Sump Tank 600*	
Prairie Island 1 & 2	2 - 5		2 @ 1,000*	Sump Tank 600* Aerated	SGBD Demins not for Waste Handling
Beaver Valley 1 & 2	6	1,350*	2 @ 3,000*	Decon Drain 1,400*	
J. M. Farley 1 & 2	15	?	5,000	Floor Drain 10,000	
Sharon Harris	Fluid Bed Dryer	5,000		Floor Drains 4 @ 25,000	
North Anna	6 Clarifier		2 @ 1,500	Lo Level Waste 2 @ 11,250	
H. B. Robinson		925	2 @ 1,000	Waste Condensate 3 @ 11,250	
San Onofre	ion exh / gas stripper			Decon Drain 2,600	4 - 35 ft ³ Waste Processing Demins
V. C. Summer		5,000	5,000	Floor Drain 10,000	
Surry 1 & 2	not used			Lo Level Waste 2 @ 2,875	5 - 10 ft ³ Waste Processing Demins
Turkey Point	2 - 15				
Byron 1 & 2	3 - 30	6,400*	2,000*	Aux Bldg Floor Drain 2 @ 8,000	

Table 15.1-2 (cont'd)
Liquid Waste Evaporators and Miscellaneous Tanks

Plant Name	Waste Evaporator Capacity (gpm)	Waste Evaporator Concentrate Tank	Waste Evaporator Condensate Tank	Miscellaneous Tank	Comments
Braidwood	3 - 30	6,400*	2,000*	Aux Bldg Floor Drain 2 @ 8,000	
Calloway			5,000	Floor Drain 2 @ 10,000	2 @ 5,000
Catawba	1 - 15	3,000	5,000	Floor Drain 10,000	Cont. Vent Unit Drain 5,000
Commanche Peak	1-15	5,000*	5,000*	Floor Drain 2 @ 10,000	Waste Dvaporator Floor Drain Rev. Osmosis - Laundry
D.C. Cook	2 - 15 and 1 - 2	4,000*	2 @ 1,500*		
Diablo Canyon	Mobile Rad Waste	2,000		Floor Drain 2 @ 10,000 1 @ 30,000	Mobile Radwaste Purification (Chem Nuclear)
McGuire 1 & 2	1-15	3,000	5,000*	Floor Drain 2 @ 10,000	Cont. Vent Cond. Drain 4,000
Millstone 3	1-35			Lo Level Waste Drain 2 @ 4,000	
Salem				Concentrates Holding Tank 500	
Seabrook 1 & 2				Floor Drain 2 @ 10,000	
Sequoyah 1 & 2	1 - 30		3 @ 2,000*	Aux Bldg Sump 600*	Portable Filtration System (60gpm)
Trojan	1 - 15	2 @ 15,322	1,300	Dirty Waste Drain 5,900	2 @ 15,322
Vogtle 1 & 2	1 - 15	2,000*	5,000	Floor Drain 10,000	2 @ 5,000

Table 15.1-2 (cont'd)
Liquid Waste Evaporators and Miscellaneous Tanks

Plant Name	Waste Evaporator Capacity (gpm)	Waste Evaporator Concentrate Tank	Waste Evaporator Condensate Tank	Miscellaneous Tank	Comments
Wolf Creek		1,000	5,000	Floor Drain 10,000	
Zion 1 & 2	1 - 12		2 @ 8,000	Aux Bldg Sump 250	Spray Film Type Evaporator

* common to both units

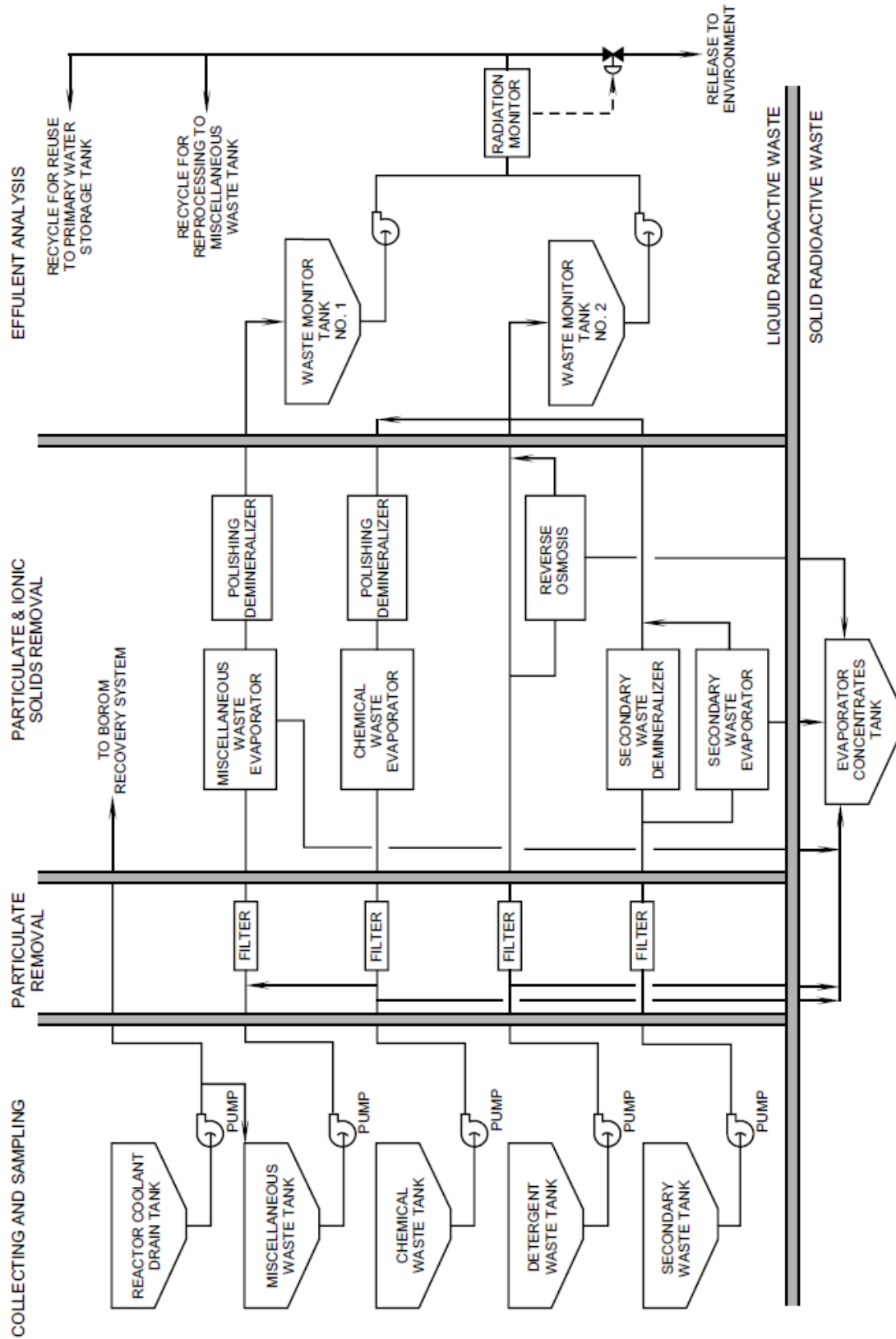


Figure 15.1-1 Liquid Radioactive Waste Processing System

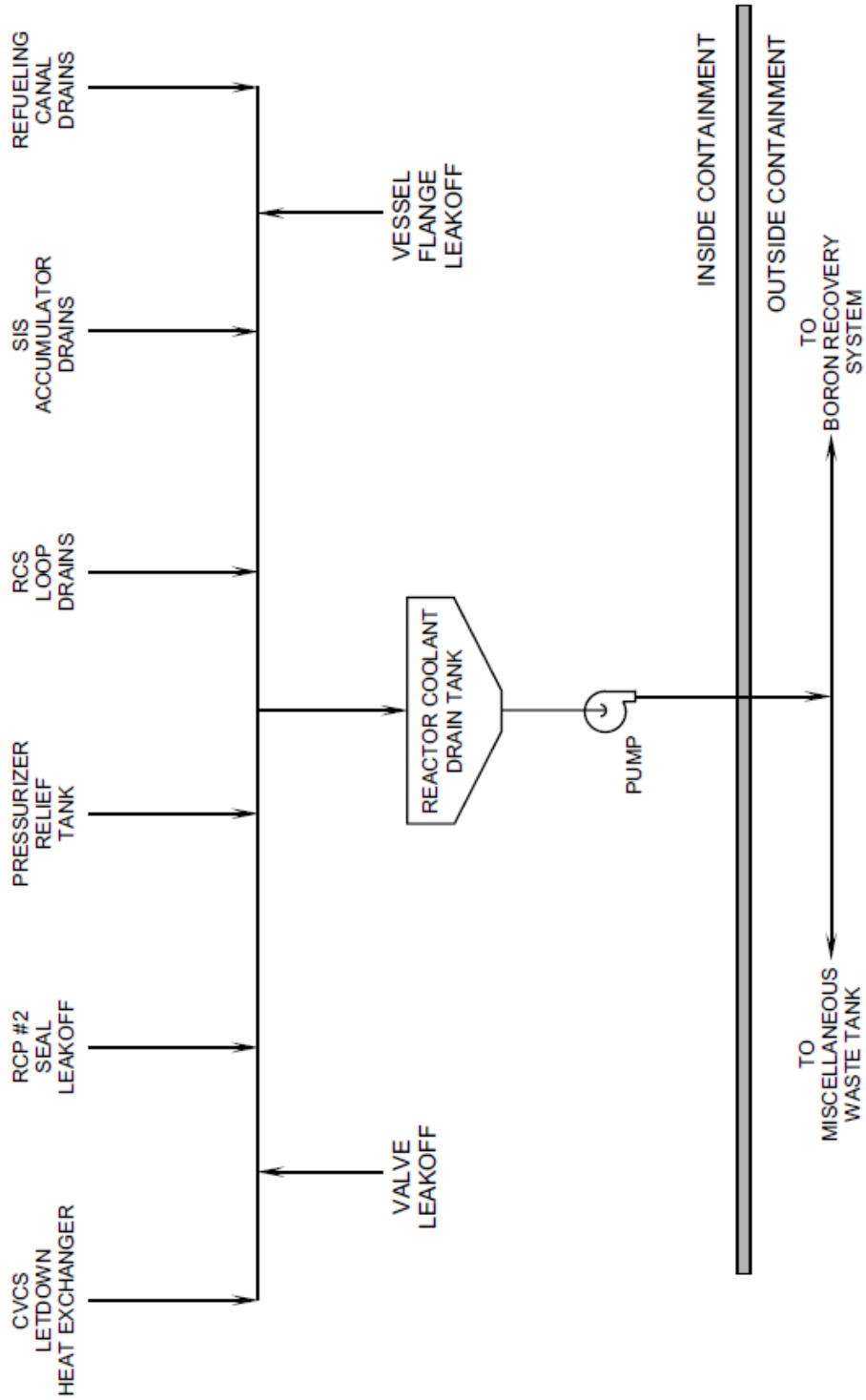


Figure 15.1-2 Deaerated Reactor Grade Water System

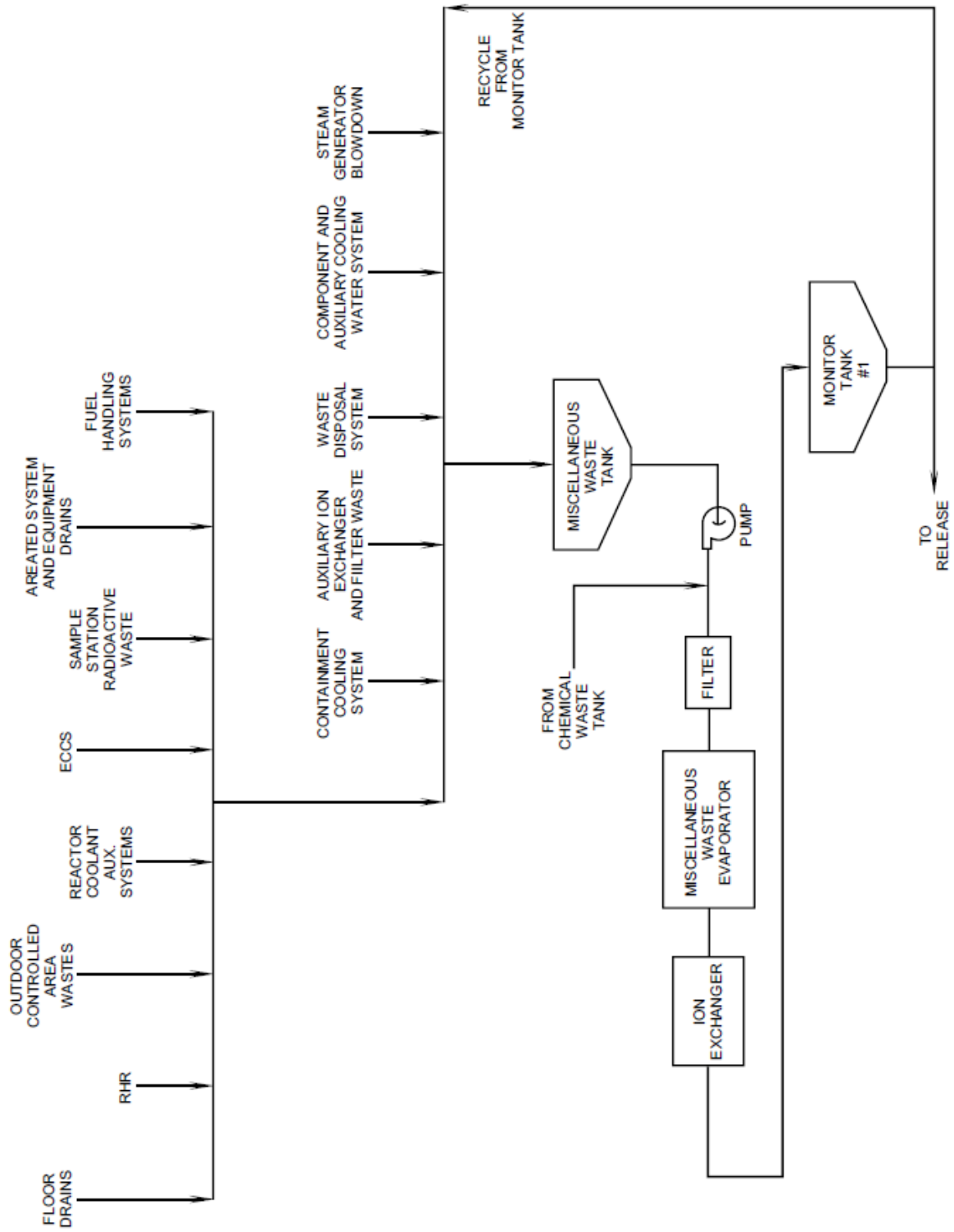


Figure 15.1-3 Miscellaneous Waste System

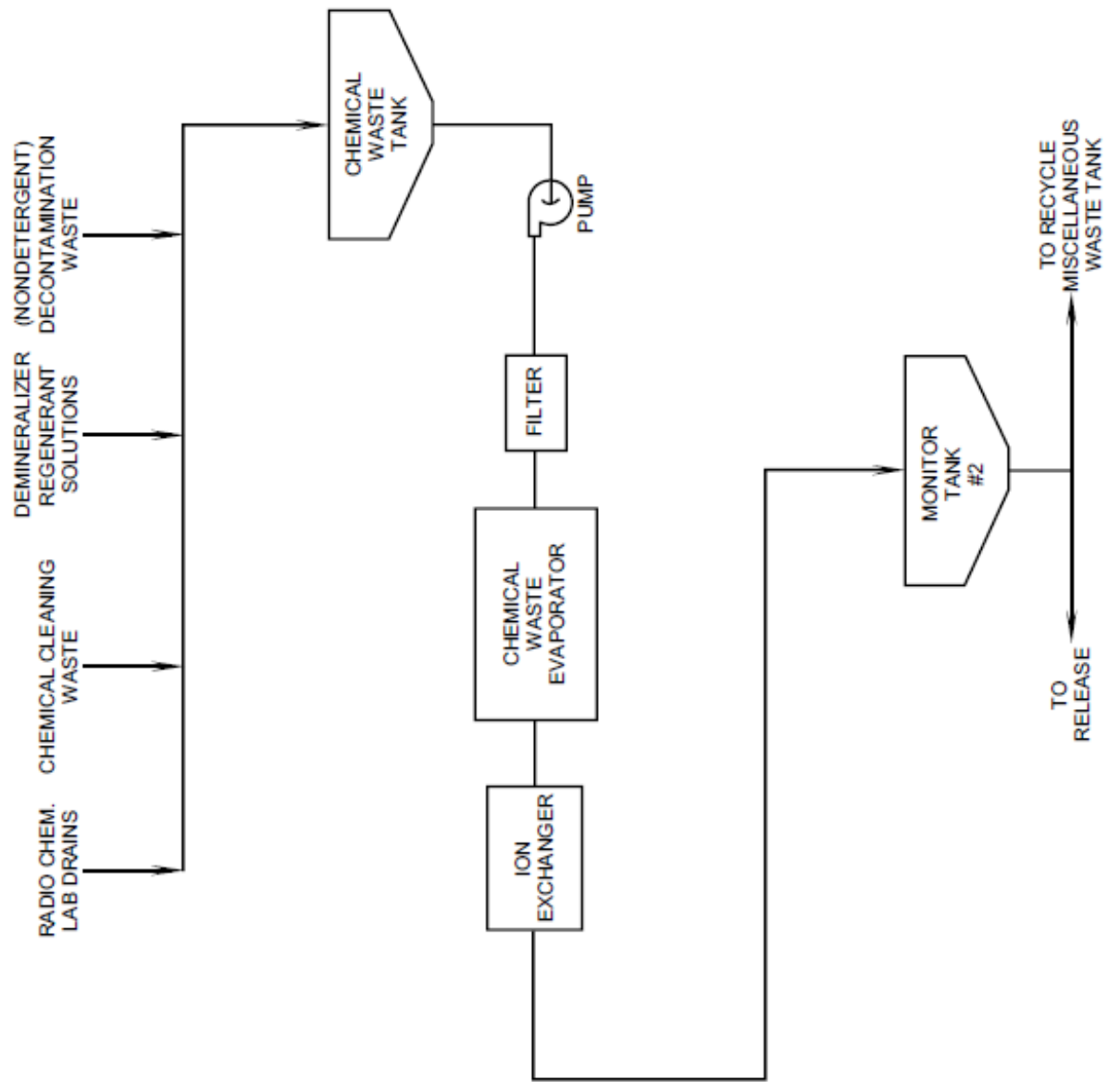


Figure 15.1-4 Chemical Waste System

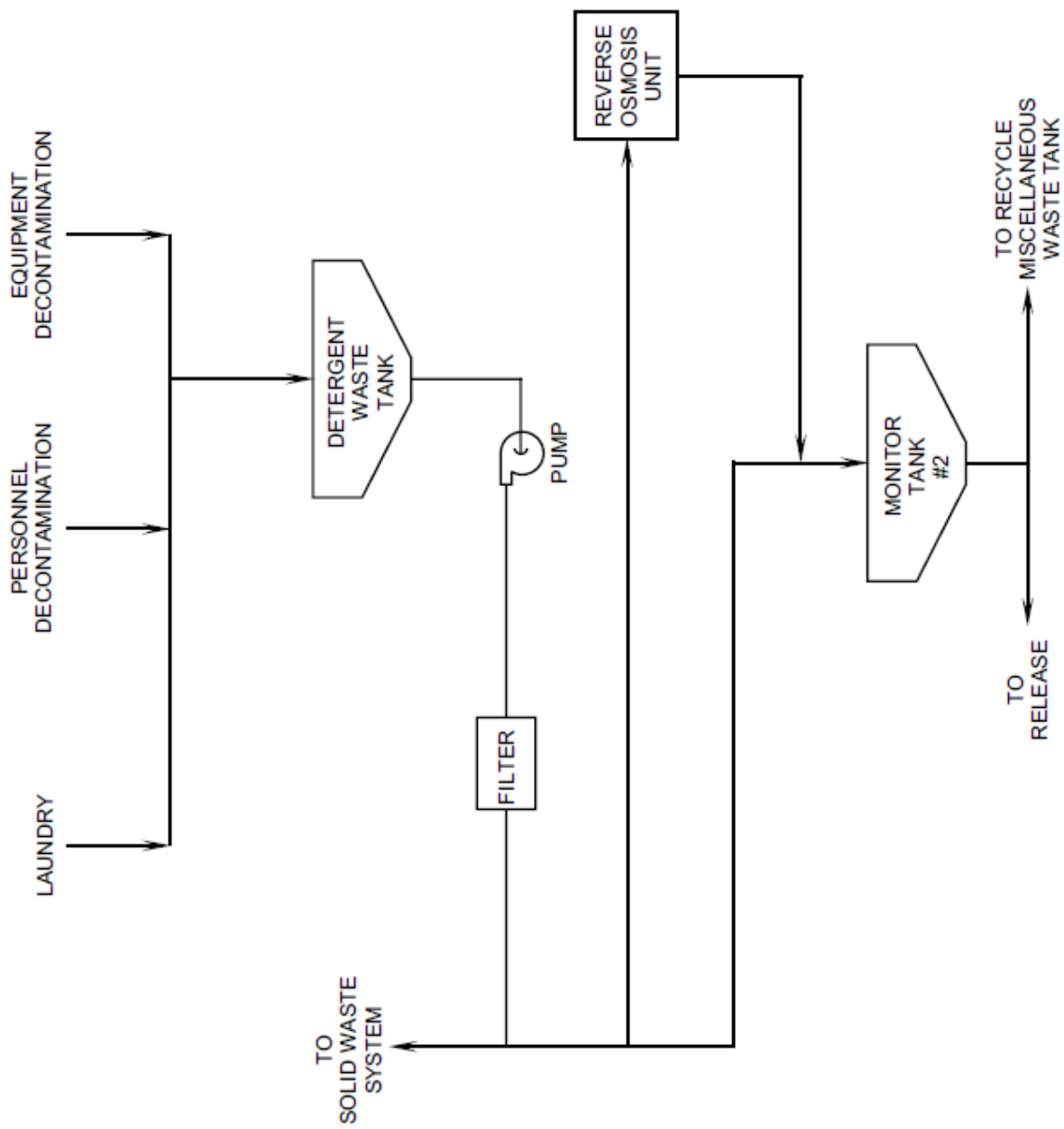


Figure 15.1-5 Detergent Waste System

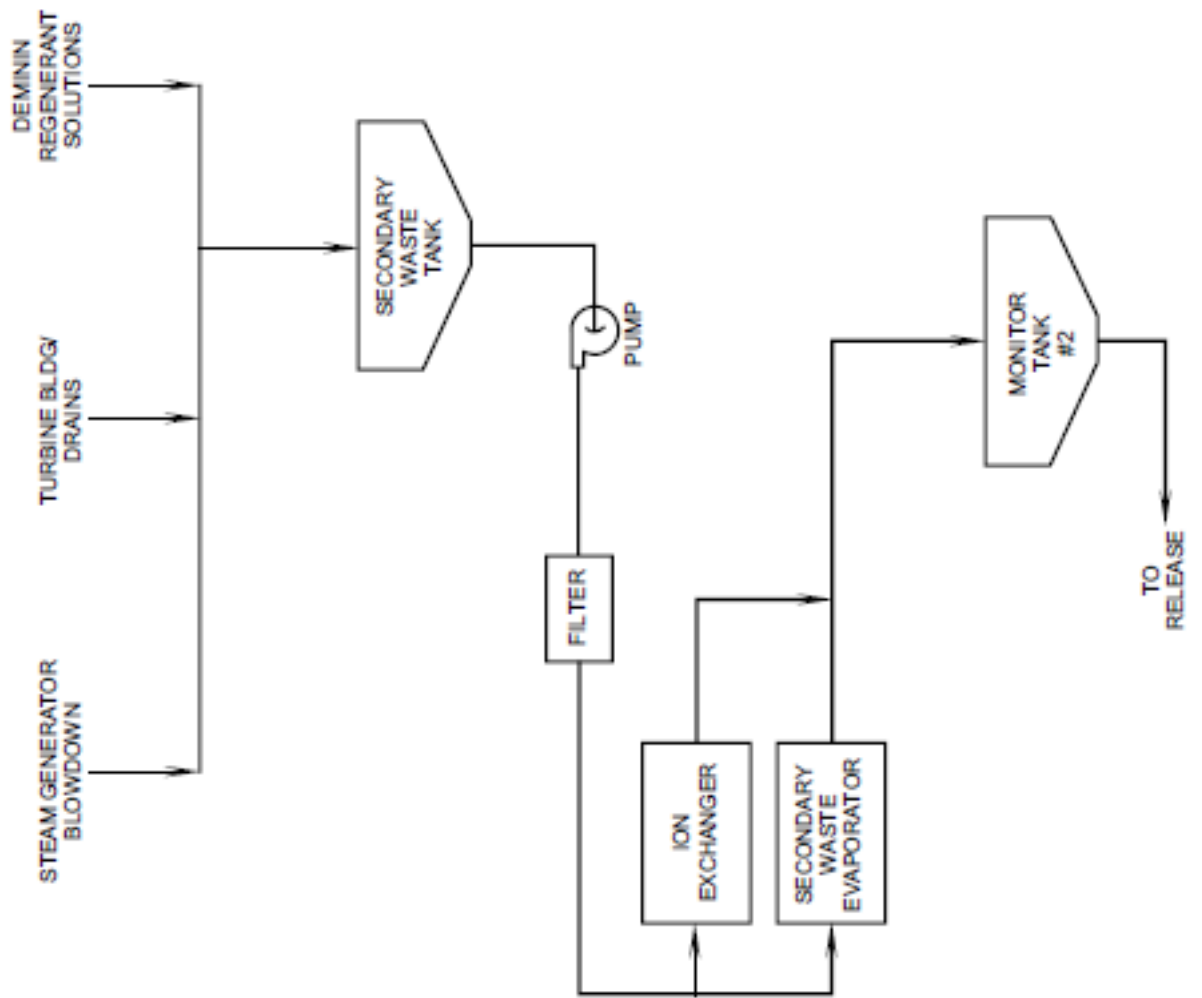


Figure 15.1-6 Secondary Waste System

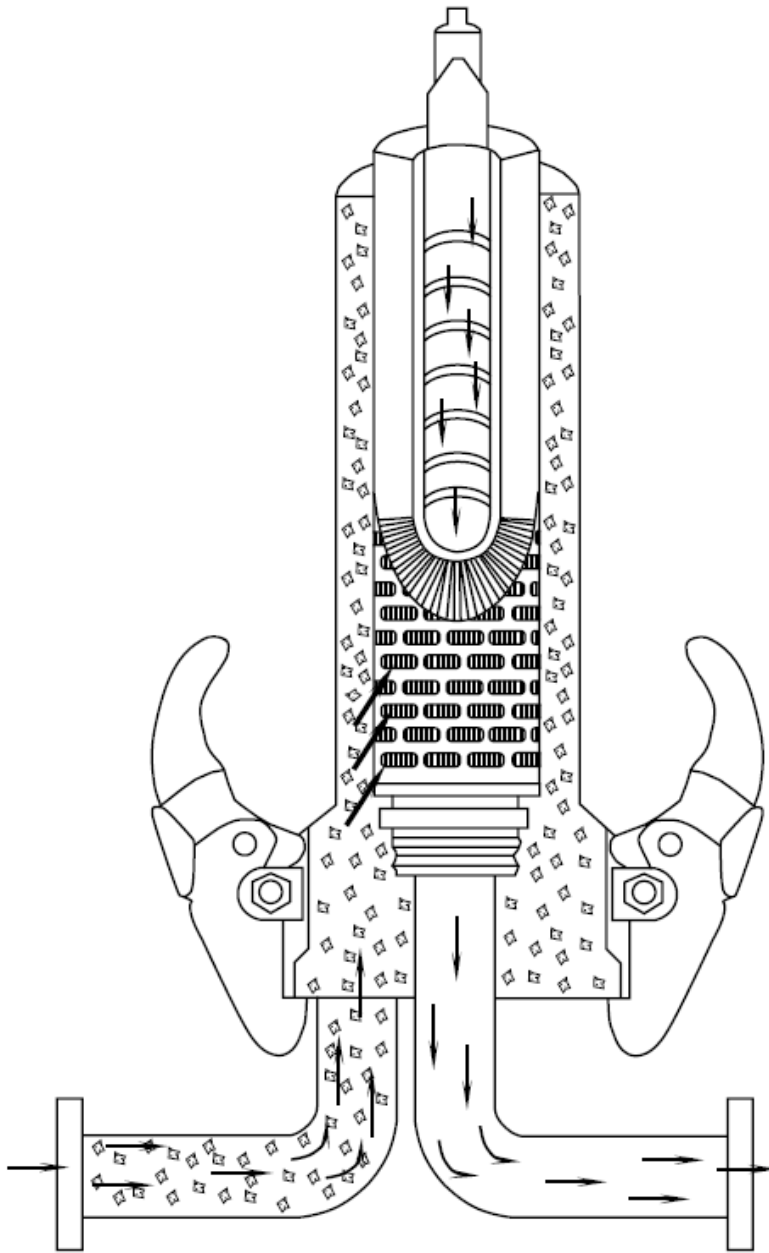


Figure 15.1-7 Cartridge Filter

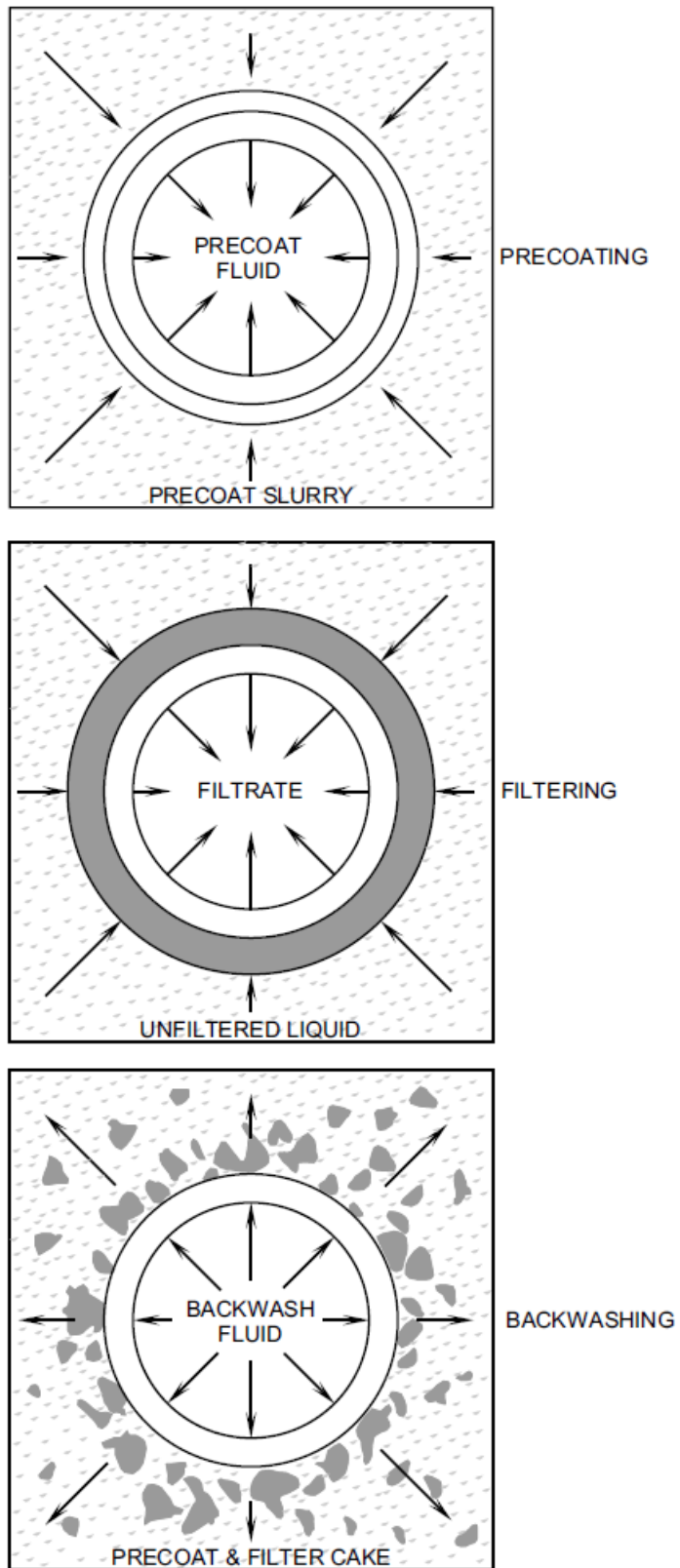


Figure 15.1-8 Precoat Filter