

Westinghouse Technology Systems Manual

Section 15.2

Solid Radioactive Waste Processing Systems

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15.2 SOLID RADIOACTIVE WASTE PROCESSING SYSTEMS

Learning Objectives:

1. List the two categories of solid radioactive waste.
2. Provide three examples of each category.
3. List and briefly describe two solidification systems.

15.2.1 Introduction

The most rapidly changing area in radioactive waste management today is that of solid radioactive waste processing. New solidification processes and agents are being used, and more emphasis is being placed on volume reduction. Increasing concern for volume reduction is a result of the lack of adequate space in commercial shallow land burial grounds, and the spiraling cost of shipping and disposal.

A past study projected that the existing commercial burial ground would soon be filled to capacity, and burial facilities are experiencing difficulty handling the large number of waste shipments that are being received. This study predicted annual volumes of solid wastes that would be well in excess of previous estimates and suggested that the capacities of most plants' solid radioactive waste (SRW) systems are under-designed by approximately a factor of two. This realization on the part of facility managements has caused the rush to add solid waste handling systems.

15.2.2 System Description

The materials destined for the SRW system are grouped into two broad categories: wet wastes, which are the results of de-watering or volume reduction processes, and dry wastes, whose volumes are reduced primarily by compacting or baling (Figure 15.2-1). The most common techniques and processes in use or planned for the SRW system are covered in this chapter. It should be understood that some volume reduction systems may not be covered and that these processing methods are strictly individual facility options. Various combinations of processing methods may be encountered at different plants.

Since all commercial burial sites prohibit the burial of liquids, the SRW system must be designed to immobilize (solidify) wet wastes into a free-standing, monolithic form. To accomplish the objective of solidification, the SRW system incorporates a number of discrete operations or subsystems. The treatment of wet wastes may be broken down into five operations:

- Waste collection,
- Waste pretreatment (de-watering/volume reduction),
- Solidification,
- Mixing/packaging, and
- Container handling.

The treatment of dry waste may be broken down into three operations:

- Waste collection,
- Mixing/packaging, and
- Container handling.

Table 15.2-1 lists the SRW systems at selected Westinghouse facilities.

15.2.2.1 Wet Wastes

The term “wet wastes” refers to contaminated wastes having sufficient water content to allow them to be pumped to collection tanks for processing. Wet solid wastes are classified into four basic types:

- Spent resin,
- Filter sludge,
- Evaporator concentrates, and
- Miscellaneous liquids.

Spent resins

Spent resins result from use of liquid radwaste demineralizers, fuel storage pool coolant cleanup (Section 14.5), and reactor coolant cleanup (Section 4.1).

Filter Sludge

Filter sludge consists of spent filters, material from precoat filters, and powdered resin from precoat filter/ demineralizers.

Evaporator Concentrates

Evaporator concentrates or evaporator bottoms result from the operation of liquid radwaste evaporators. Evaporator concentrates consist of concentrated boric acid and radioactive particulate solutions.

Miscellaneous Liquids

Miscellaneous liquids are solutions that may contain a high concentration of chemicals that make this liquid difficult to process in the liquid waste system. The miscellaneous liquids generally come from the chemical waste system.

15.2.2.2 Dry Wastes

Dry wastes are contaminated articles such as rags, disposable clothing, cleaning equipment, tools, disposable filter cartridges, and in some cases, plant equipment.

Disposable filter cartridges present particular problems due to their moisture content and high radiation levels. Filter cartridges are treated as dry waste but are processed differently than the other dry waste materials.

15.2.2.3 Collection

Demineralizer resins and filter sludge are routinely collected in separate tanks which facilitate further treatment, as they can be directed toward specific waste processes. Liquid wastes and decontamination solutions may be segregated during waste collection. Increasing the degree of waste segregation generally facilitates subsequent immobilization treatment.

15.2.3 Pretreatment Subsystems

Pretreatment is primarily directed toward reducing waste volume and thereby reducing transportation and burial costs. Wet wastes are generally in the form of slurries containing as much as 85% water. If this water can be removed and reused in the plant, the demands on the SRW system will be greatly reduced. Table 15.2-2 illustrates the need for volume reduction.

Various methods and options are available for the treatment of these wastes. The most common pretreatment systems are decanting, centrifuge, evaporation, calcination, and filtration systems.

15.2.3.1 Decanting

The process of decanting (Figure 15.2-2), has been used for several years primarily to de-water resin slurries. The spent resin is flushed out of the ion exchanger into the spent resin tank. When it is time to process the spent resin, it is pumped from the spent resin tank into the decant tank. This slurry is allowed to settle, with the resin beads dropping to the bottom of the decant tank. After settling, the decant arm, which is actually a movable pump suction tube, is lowered to just above the resin level. The position of the decant arm is determined by a sonic sensor, which can discern the resin water interface. The pump then switches the suction and discharge paths to take a suction on the bottom of the decant tank and discharges the de-watered resins to the mixing system for solidification.

15.2.3.2 Centrifuge Separation

Centrifuge separation is a method in which mechanically driven rotating devices use centrifugal force for separating substances of different densities. Several types of centrifuges are in use for de-watering radioactive waste. The most commonly found centrifuges are the tube-and-disk type and the basket type. The tube-and-disk type uses rotational force to cause the solids to migrate to the tube wall, where they can be collected, and the clear liquid overflows the tube. The basket or filtering type forces liquid through a rotating screen, which collects the solids and allows the clear liquid to flow through. Centrifuges are most commonly used to de-water resin slurries and precoat filter materials.

15.2.3.3 Evaporation

Evaporators have a wide range of uses in the management of radioactive wastes, and as explained earlier (section 15.1.2.3), evaporators are effective in the volume

reduction of wastes. There are many different types of evaporators in use that meet the requirements of the SRW system. The thin-film evaporator is one type in use (Figure 15.2-3).

The advantage of the film evaporator (wiped-film dryer) is its capability to evaporate to high waste product concentrations. The heating surface is a cylinder which contains a rotating blade or series of wipers, maintained at a fixed close clearance from the cylinder inner wall. The cylinder is externally heated by a steam jacket or other heat source. Liquid waste is fed into one end of the cylinder and agitated by the rotating blades, which wipe the waste film from the heated cylinder. Partial evaporation from the film occurs quickly, and subsequent blade travel continuously redistributes the concentrate film as it progresses toward the discharge end of the cylinder.

The water product is discharged in the form of a liquid, slurry, or free-flowing solid. This discharge material is then solidified in another portion of the SRW system.

15.2.3.4 Calciner System

Calcination is a high temperature process in which wastes are dried and thermally decomposed to form stable, nonfused compounds such as oxides. To date, much of the developmental work in calcination has been directed toward treatment of high level wastes. The end product from calcination represents minimum volume and can be powdery dusts, free-flowing granular material, or a porous friable cake. In calcination systems, various liquid wastes are sprayed into a direct-fired calciner vessel. Here the liquid flashes to steam, as the droplets come in contact with the vessel. Heat for this process is supplied by burning a combustible fluid. The dry, calcined product is collected from the vessel and transferred to the solidification portion of the SRW system.

15.2.3.5 Filtration

Solid waste products can be generated by filtration. Filtration systems commonly used in the pretreatment of wet wastes are reverse osmosis and precoat filters. These units are discussed in Section 15.1. In reverse osmosis or precoat filtration, the impurities are deposited on the membrane of the reverse osmosis unit or the precoat material of the precoat filter. Essentially pure water passes through these units and is collected in the monitor tanks, from which its ultimate disposal is determined. During operation, the membrane or precoat material becomes saturated with impurities. After saturation, the impurities, along with the membrane or precoat material, are solidified.

15.2.4 Solidification

In this operation, the wet solid wastes are incorporated with a solidification agent to form a monolithic free standing solid. The basic solidification agent types are:

- Cement,
- Urea formaldehyde,

- Bitumen (Asphalt), and
- Other polymer systems.

15.2.4.1 Cement Systems

Cement is used to solidify free liquids by chemically binding the heavy liquid waste into a crystal like structure. Different mixtures and ratios of cement and additives are used, depending upon the type of waste to be solidified. Cement has been commonly used as a solidification agent and is generally acceptable to all burial sites.

The optimal proportions of waste and cement and the type of cement chosen vary with the system type and its composition. Cement requires a minimum amount of water to obtain workability. This minimum water-to-cement ratio is approximately 25% by weight for Portland Cement. The addition of too much water may result in a layer of free standing water on the surface of the solidified product. Boric acid and borate salts retard setting in Portland Cement. Therefore, if sufficient quantities of borated water are added to the cement, the set may be retarded to an extent that the cement may never harden. In the case of waste resins, filter sludge, and powder, liquid waste or pure water may be added to form an acceptable mixture for good setting properties. To aid in the solidification process, sodium silicate is used as an additive to increase the waste/cement ratio. Sodium silicate is especially effective when the waste contains boric acid or borate-salt solutions.

The two basic types of cement solidification systems are the drum tumbling mixing system and the in-line mixing system (Figure 15.2-4). The primary difference lies in where the mixing of the cement and waste occurs. Advantages of cement as a solidification agent are its availability, low cost, fire resistance and well-known characteristics. Disadvantages include post-leachability and problems with solidification if the correct waste/cement ratios are not maintained. All operations are carried out with remote handling equipment located in shielded areas. Automatic sequences simplify individual processes and reduce the possibility of operator errors. Special shielding arrangements have been established to improve access to equipment requiring routine maintenance.

15.2.4.2 Urea Formaldehyde Systems (Installed but not Used)

Urea formaldehyde (UF) resin is a liquid emulsion of urea and formaldehyde chemically combined into polymeric chains. This resin can be readily mixed with water. When an acid catalyst is added to the resin/water solution, a condensation mechanism occurs and a solid is formed. The water that was added to the resin is now entrapped in this solid polymer matrix. Several different acids may be used as the catalyst. Polymerization is pH dependent, and the amount of catalyst necessary to produce a waste/UF mixture pH of approximately 1.5 must be determined for each waste processing batch. The resulting formulation will begin to gel within several minutes after the addition of the required quantity of catalyst and will generally form a free-standing solid within thirty minutes. The polymerization reaction may, however, continue for several hours, during which small quantities of acidic free standing water may be released. Figure 15.2-5 shows a simplified schematic of the UF process flow. As in the case with cement, the UF mixing

process can be carried out either in an in-line mixer or directly in the burial container. In both cases, the catalyst is added last to avoid the problems associated with premature resin setting.

15.2.4.3 Asphalt Extrusion (Installed but not Used)

Bitumen or asphalt is a mixture of high molecular weight hydrocarbons obtained as a residue in petroleum or coal tar refining. Several types of bitumen systems are available, but the direct distillation product is one of the most widely suggested for radwaste solidification. The asphalt extruder system reduces the volume of waste and causes solidification all in one step.

In this process (Figure 15.2-5), asphalt and either liquid or sludge wastes are continuously pumped into one end of a screw extruder, which may contain one or multiple screws. The design and operation of the extruder is such that the asphalt and waste are intimately mixed and spread into a thin film on the heated surface of the extruder barrel. This mechanical processing together with the maintenance of a temperature of approximately 200°C effects the almost complete (99.5%) evaporation of the water contained in the waste and provides a homogeneous product. The evaporated water is vented through sections called steam domes and passed through oil separators before being condensed. The number of domes needed depends on the size of the extruder needed to evaporate 99.5% of the water out of the waste input.

Evaporation rates from the various size extruders range from 0.25 gal/hr to 50 gal/hr. The asphalt-waste mixture is discharged directly into the solidification containers at the end of the extruder and allowed to cool. The asphalt extruder system does have some specific problem areas. One is the oil carryover that can occur in the steam domes. This carryover would cause serious clean up problems. The second disadvantage of this system is that asphalt burns, and there is some evidence that the incorporation of oxidizing agents increases the fire risk.

15.2.4.4 Polymer Systems

Binder 101 is a commercially available modified vinyl ester resin. For solid waste, the dry product is coated with solidification agents and solidified by cross linking of the polymer.

The solidification agent is blended with the quantity and type of promoter required by the pretested formulas at the filling station during the drum filling process. Catalyst in a stabilized condition is added to the drum via the in-drum mixer at the end of the drum filling process. Stabilization of the catalyst permits it to be located in close proximity to the polymer for an indefinite period of time without catalysts. Catalyst is dispersed into the binder/promoter moisture during the verification phase that takes place within the drum processing enclosure during the drumming process. Because formation of the binder/waste stream mixture does not require high energy mixing, a temperature rise (less than 5°F) due to mixing can be ignored. Quantities of binder, promoter, catalyst, and waste are determined by verification testing of the individual simulated waste stream.

The binder works as a solidification agent by surrounding the waste stream and physically entrapping it after polymerization. Generally, there is no chemical reaction between the waste stream and the solidification agent, as there is with cement and liquid wastes. Once addition of the waste stream is complete, the reaction proceeds by first gelling and finally becoming a solid block. The cross-linking reaction is exothermic. The exothermic reaction is not noticeable until the polymer-waste mixture has gelled and begun to harden.

Solidification of this dry product requires that the dry product enter the drum at a temperature below 13°F. Although at higher temperatures the viscosity is reduced, which promotes mixing, the high temperatures have an adverse effect in that the polymerization process is accelerated.

15.2.5 Drumming

Prepared Department-of-Transportation-approved drums are placed in the drumming room. The waste product is transferred to the drums. After the proper amount of waste material has been added, the filling process is terminated. When the drums have been properly capped, they are transferred to a temporary storage area until shipment to a burial site. It should be noted that almost all steps in the drumming process to storage are performed remotely.

15.2.6 Dry Waste Packaging

Contaminated articles such as rags, disposable clothing, cleaning equipment, tools, and in some cases, plant equipment are disposed of as dry waste. Most nuclear plants have a dry waste bailer or compactor to reduce the volume of loose dry waste prior to shipment to a licensed burial site. Disposable filter cartridges present a problem due to abnormally high radiation levels. They are usually placed in special shielded casks for off-site disposal. The compaction, baling, or casking operations that the dry wastes undergo are usually performed from remote locations.

15.2.7 Summary

Operating costs for the handling of radioactive wastes have risen to the level of several million dollars per year with no indication of leveling off. Therefore, much of the development and backfitting of the solid radioactive waste systems are directed toward reducing the total volume of packaged waste being shipped off-site. The SRW system is designed to handle both wet and dry wastes.

Wet wastes may be de-watered by using various pretreatment systems prior to solidification. The de-watered waste is then solidified into a free-standing form using some type of solidifying agent such as cement. Dry wastes are either baled or compacted to reduce their volume. The drumming station is design to be remotely operated to limit the radiation exposure received by plant personnel.

**Table 15.2-1
Solid Waste Processing Systems**

Plant Name	Licensed Disposal Contractor	Solidification Agent	Catalyst Agent	Comments
R.E. Ginna	No	Cement		
Kewaunee	No			
Point Beach 1 & 2	No	Cement		
Prairie Island 1 & 2	No			
Beaver Valley 1 & 2	No	Cement		
J. M. Farley 1 & 2	Yes	Cement		Hitman type disposable demineralizers. System is also used to process CVCS holdup tanks
Sharon Harris	No	Cement Vinyl Ester Polymer		Cement used for spent resins. VEP used for decanted dry salts
North Anna	Yes	Cement		UF system installed, not used.
H. B. Robinson	No	Cement		
San Onofre	Yes	Cement		
V. C. Summer	Yes	Cement	Sodium Bisulfate & Calcium Hydroxide	
Surry 1 & 2	Yes	Cement		Liquid Waste Demineralizer Subsystem
Turkey Point	No	Cement		
Byron 1 & 2	No	Cement		Cement used for liquid and resins. Polymer used for fluidized bed dryer salts from evaporator bottoms.

Table 15.2-1 (cont'd)
Solid Waste Processing Systems

Plant Name	Licensed Disposal Contractor	Solidification Agent	Catalyst Agent	Comments
Braidwood	No	Cement		Cement used for liquid and resins. Polymer used for fluidized bed dryer salts from evaporator bottoms.
Calloway	No	Cement		Decant tank used to de-water resins and charcoal slurries prior to solidification.
Catawba	Yes	Cement		Mobile solidification unit
Comanche Peak	Yes			Mobile solidification processing skid. ACTOR system (Topical Report ATC-132A)
D. C. Cook	Yes	Cement		
Diablo Canyon	Yes	Cement		Mobile Radwaste Purification System
McGuire 1 & 2	Yes	Cement		Waste Solidification pad. UF system installed not used
Millstone 3	No			Portable Solidification Unit
Salem	No	Cement		
Seabrook 1 & 2	Yes	Cement		Mobile Solidification contractor. Plant set up to use asphalt extruder
Sequoyah 1 & 2	Yes	Cement		Mobile Solidification System
Trojan	No	Tiger Lock (Cyanaloc-62)	Sodium Bisulfate	50 ft ³ Disposable Liners

Table 15.2-1 (cont'd)
Solid Waste Processing Systems

Plant Name	Licensed Disposal Contractor	Solidification Agent	Catalyst Agent	Comments
Vogle	No	Cement		Cement used for liquid slurry wastes. Polymer used for dry product wastes from volume reduction system. Fluidized bed dryer produces dry product wastes
Wolf Creek	No	Cement		Decant tank used to de-water resins and charcoal prior to solidification.
Zion 1 & 2	No	Cement		

Table 15.2-2
Volume Reduction

Process	55-gal Drums/yr (Approx.)
1. Drum packaging with cement; no de-watering or volume reduction	4500
2. Drum packaging with cement; volume reduction	500
3. Drum packaging with urea formaldehyde polymer; no de-watering or volume reduction*	2500
4. Drum packaging with urea formaldehyde polymer; volume reduction*	200
5. Drum packaging with asphalt extrusion/ evaporator process	280

*installed but not used at selected facilities

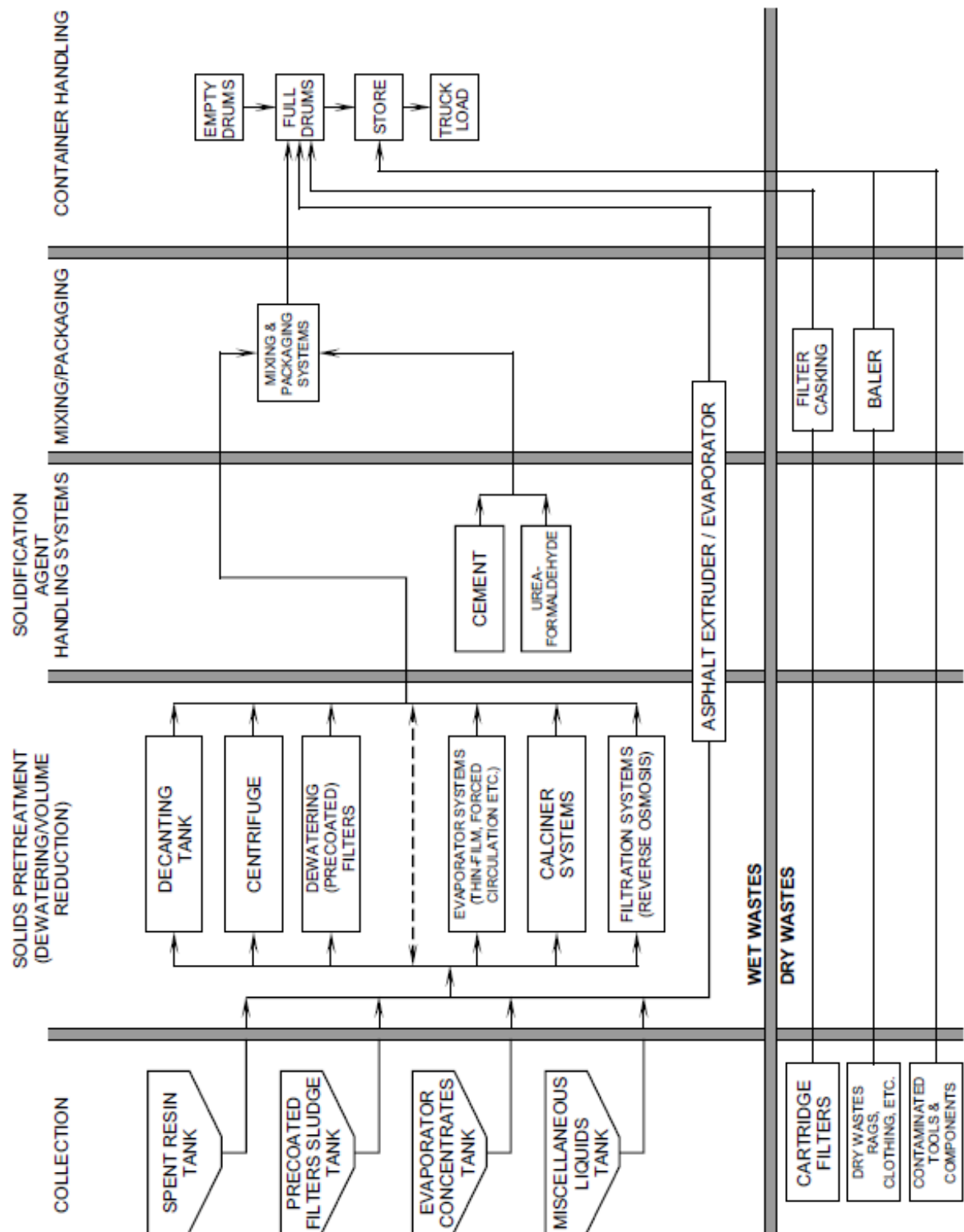


Figure 15.2-1 Solid Waste Processing Flow Diagram

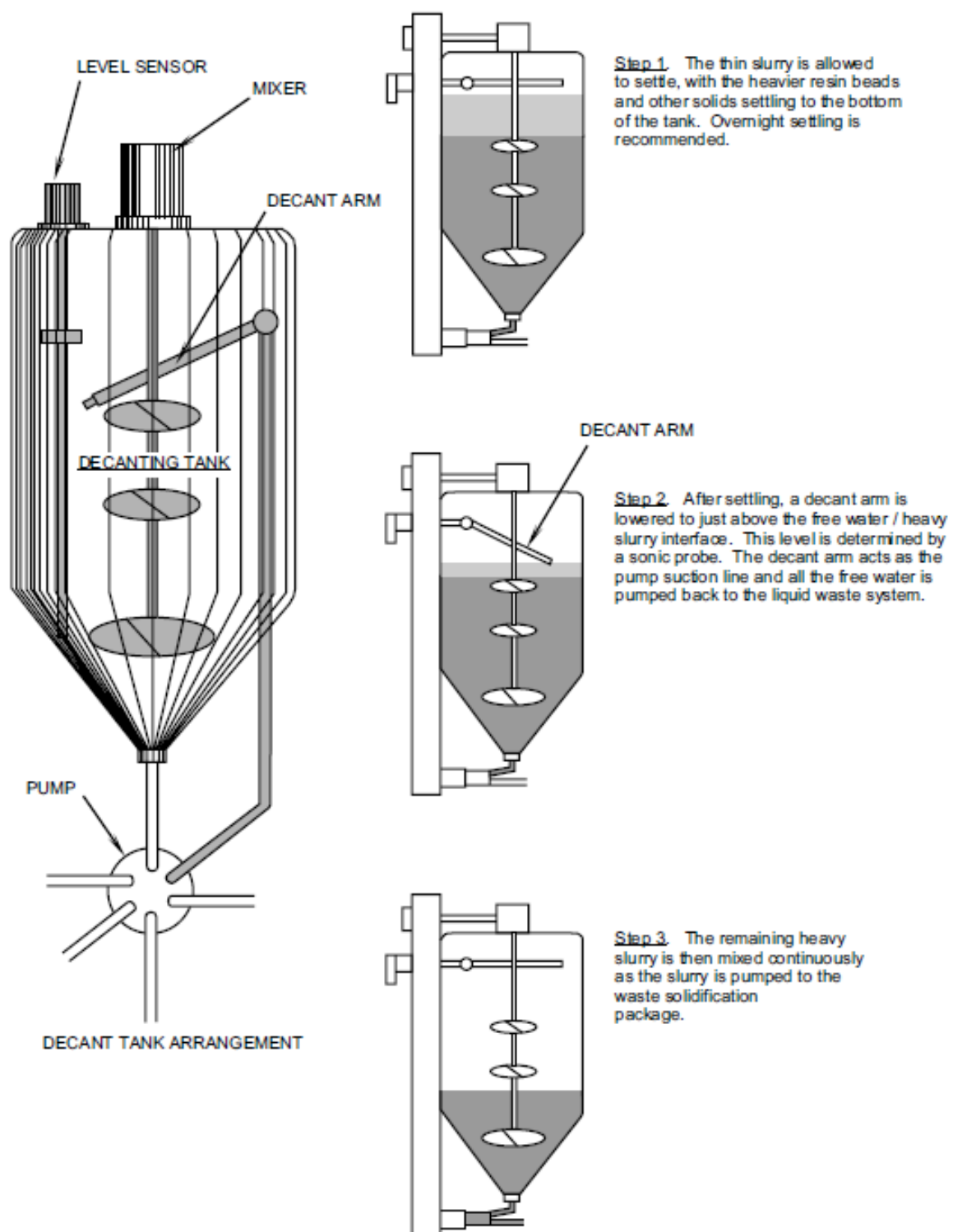


Figure 15.2-2 Decanting Tank System

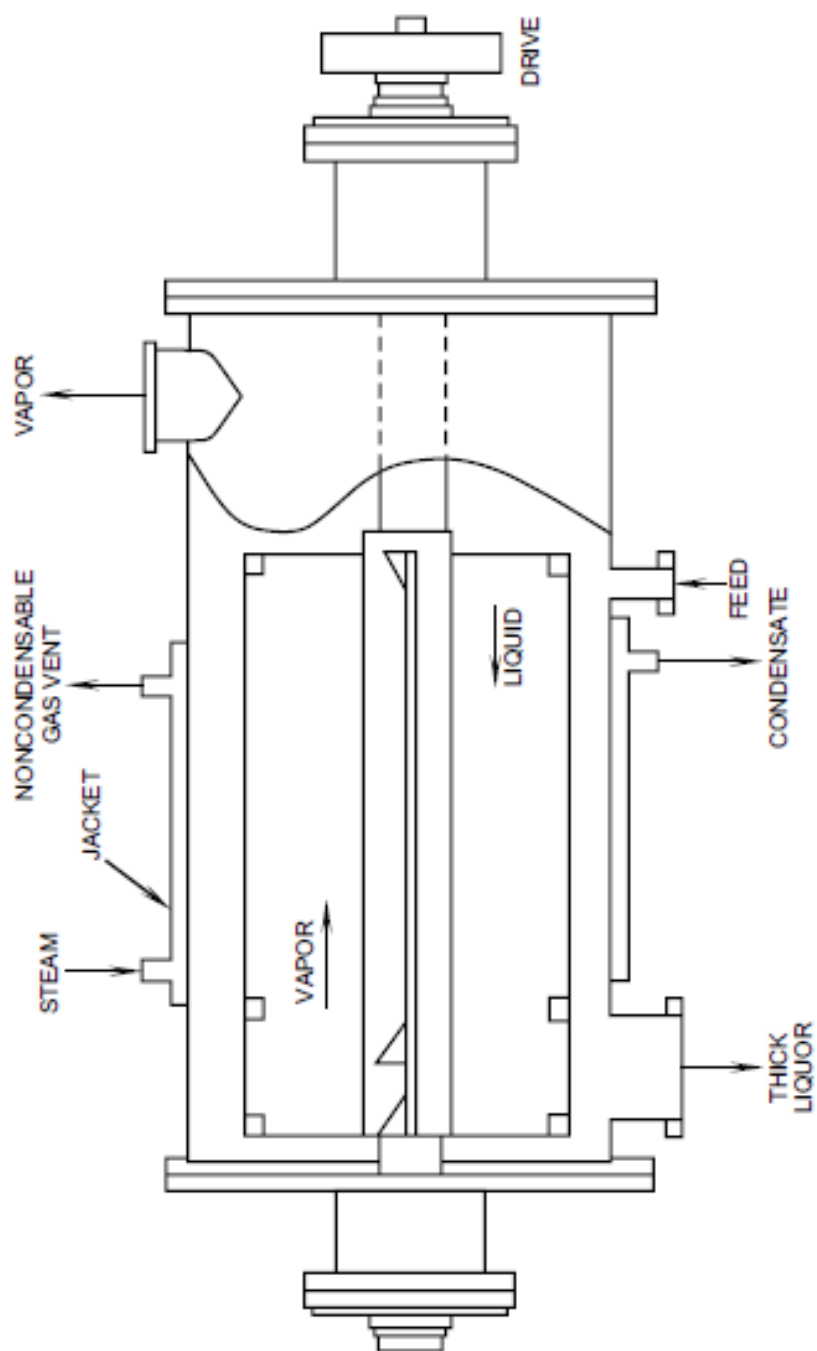


Figure 15.2-3 Wiped - Film Evaporator

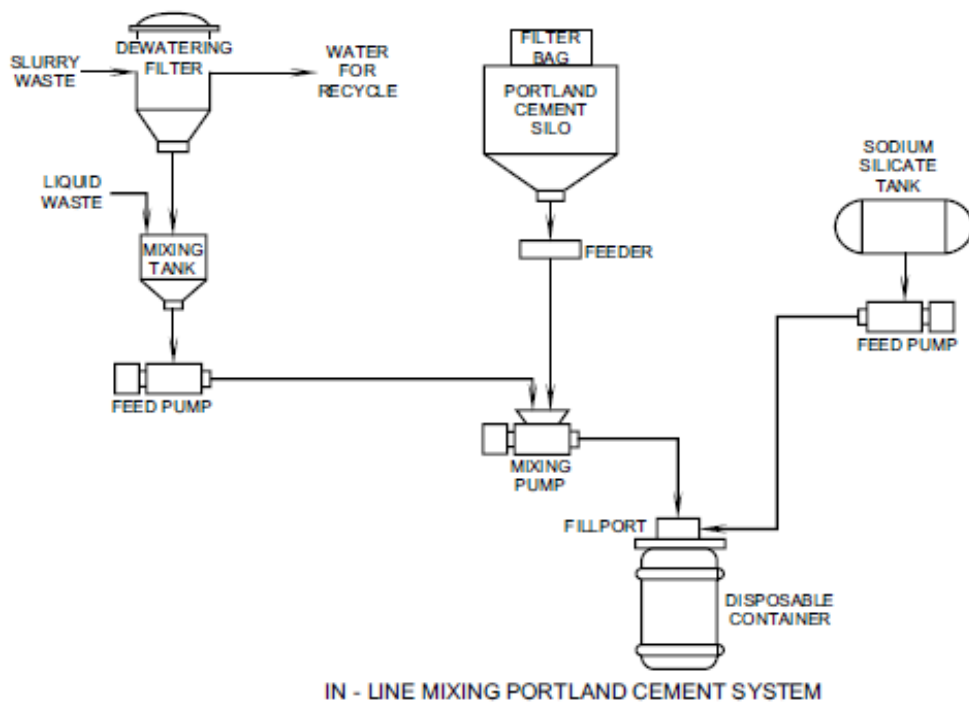
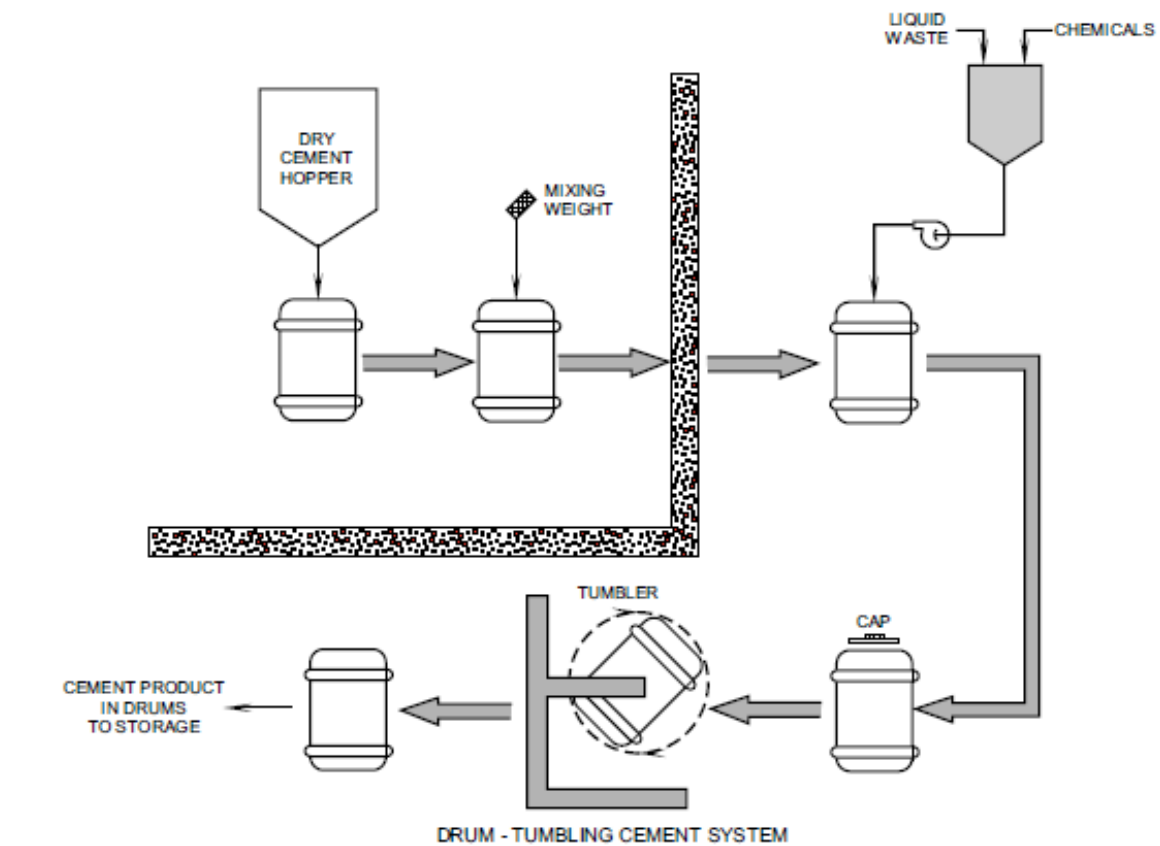
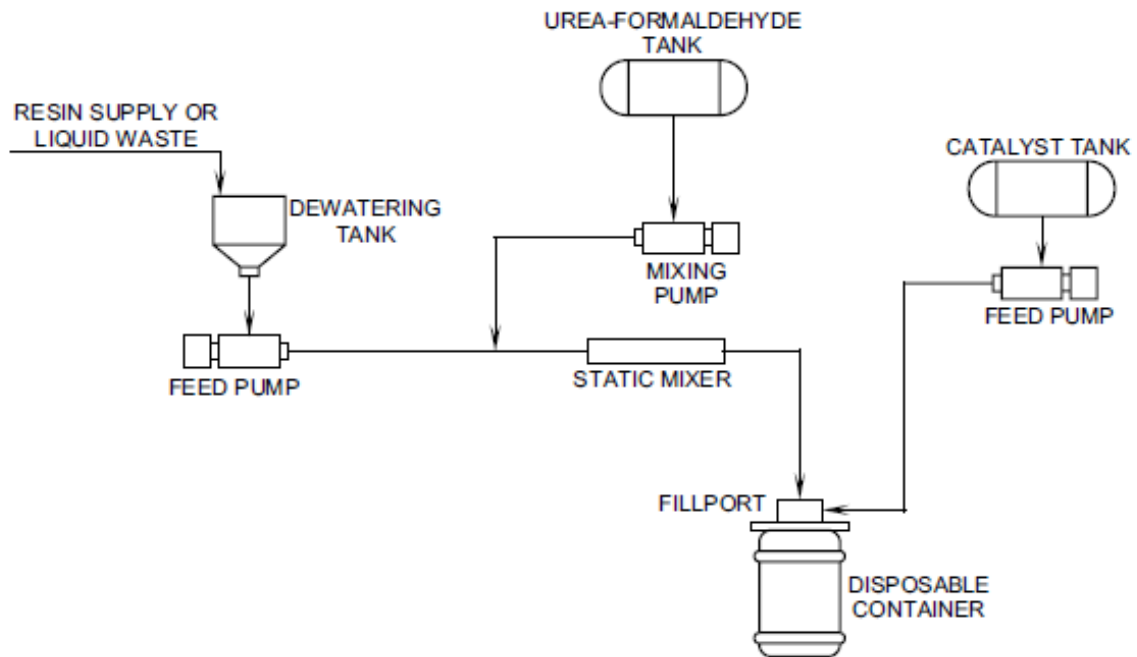


Figure 15.2-4 Cement Systems



IN-LINE UREA-FORMALDEHYDE SOLIDIFICATION SYSTEM

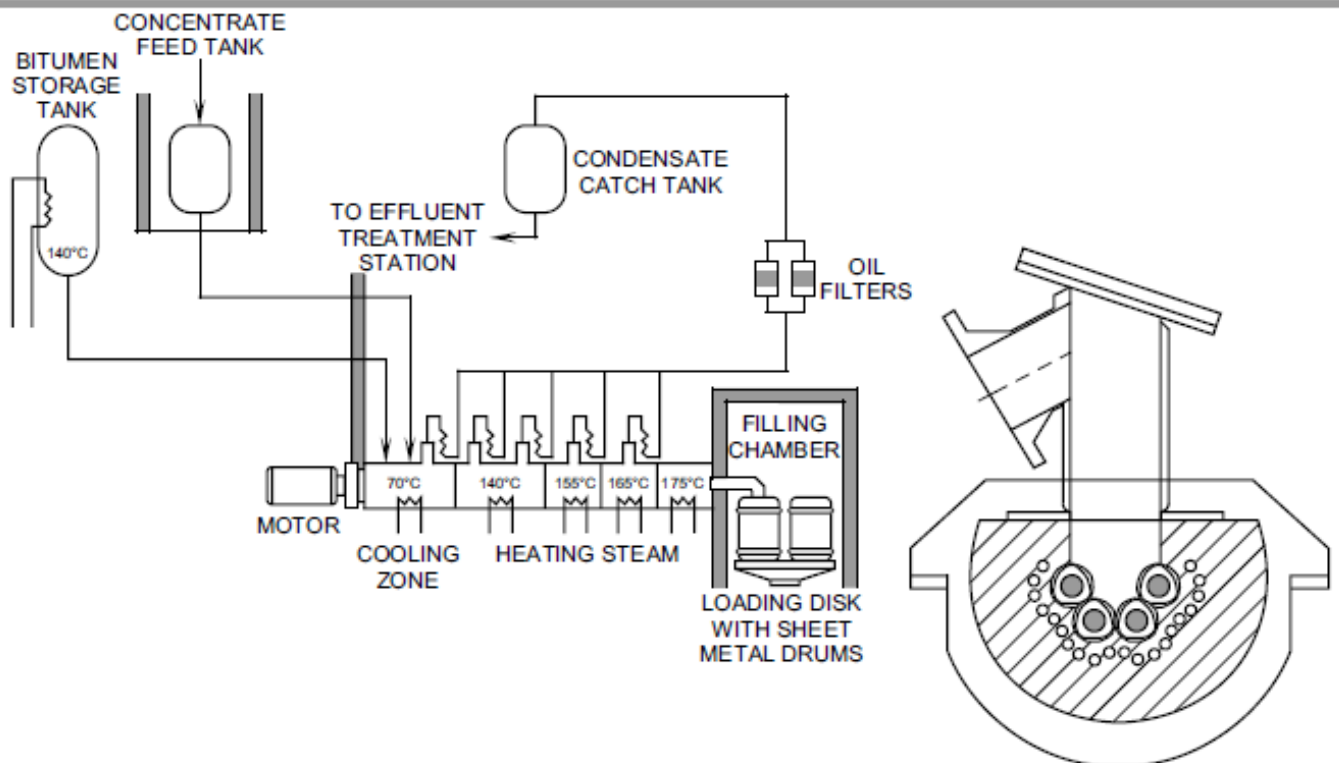


Figure 15.2-5 UF and Asphalt Solidification Systems

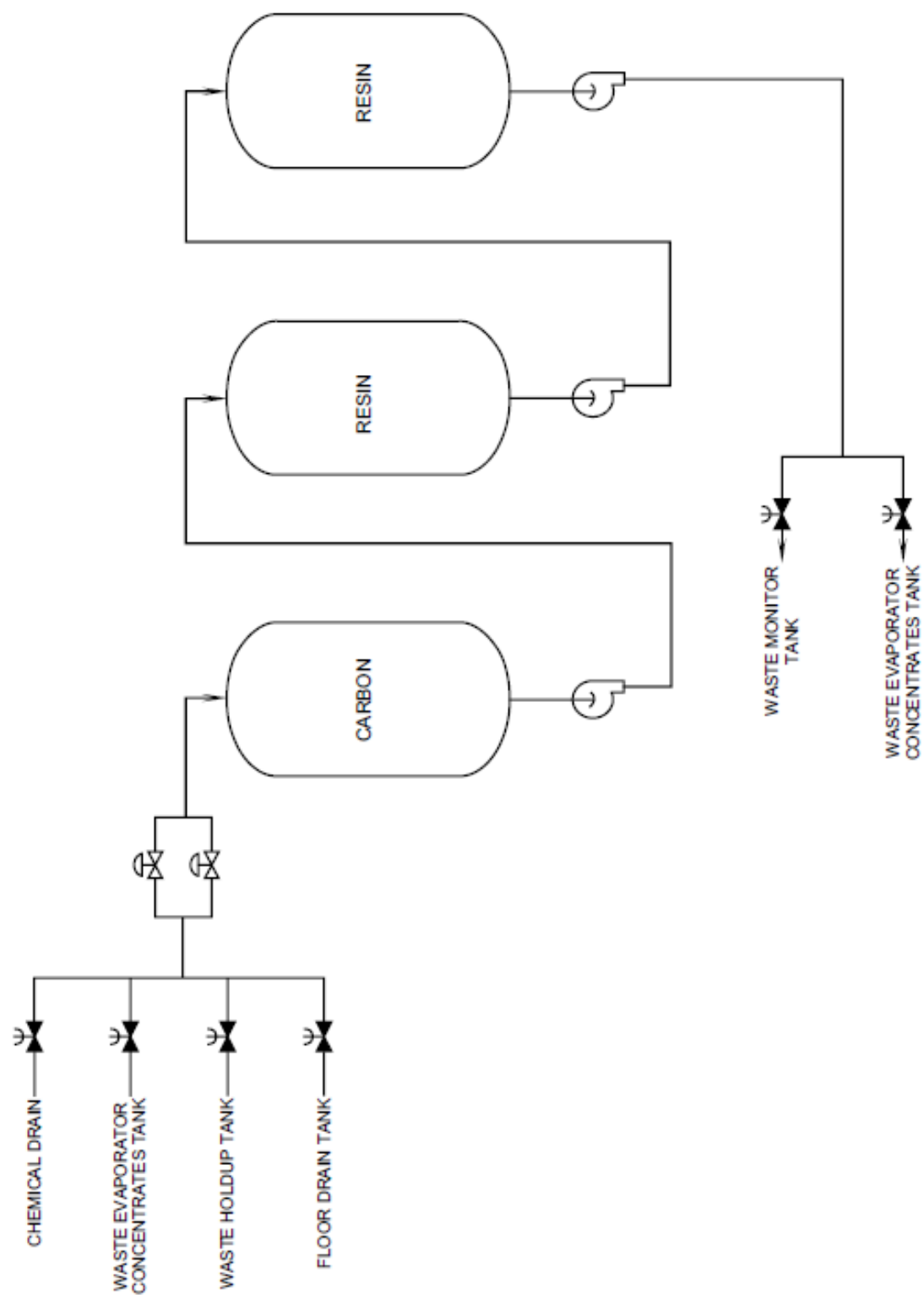


Figure 15.2-6 Three Tank Demineralizer System