

5.0 SOLID WASTE SOURCES AND ACTIVITY

Nuclear power reactors generate various types and quantities of solid radwaste as a result of processing contaminated liquid and gaseous effluent, as well as other solid materials that become contaminated through incidental or designed contact with radioactive materials at LWRs.

This chapter summarizes solid radwaste generation from typical PWR and BWR units and presents a comparison of waste generated by the two types of plants.

5.1 SUMMARY OF LWR SOLID RADWASTES

Solid radwastes generated by LWRs units consists of:

- Dry Active Waste (DAW)
- Spent ion exchange resin (primarily bead resin)
- Filters and/or filtration media
- Miscellaneous solidified liquid/wet wastes.

For the purpose handling and processing, these are broadly categorized as DAW and wet solid wastes.

Depending upon individual plant operations, units may generate all or only some of these waste streams. For example, some plants experience relatively significant steam generator tube leaks (primary to secondary) resulting in the radioactive contamination of the plant's condensate polishing resins (usually powered resin), while other plants with little or no leakage do not dispose of condensate polishing resins as radwaste. Some older plants do not even have a condensate polishing system for secondary side processing.

Tables 5.1-1, 5.1-2 and Figure 5.1-1 illustrate the relative composition of the DAW waste stream generated by both PWR and BWR units.

5.2 DRY ACTIVE WASTE SOURCES

Dry Active Waste (DAW) is generated as a result of work performed in contaminated areas and on contaminated systems. Dry waste generation rates vary from plant to plant and are largely dependent upon the operating condition of the plant. Typically, plants generate significantly more (4 to 5 times more) DAW during outage conditions than during normal operations because of increased work inside the containment and on contaminated systems vital to plant operations.

Actions that account for the majority of DAW generated by a typical LWR unit include:

- **Housekeeping:** Activities performed on a routine basis to keep the plant clean and free of debris.
- **Corrective and Preventive Maintenance:** Activities performed to keep equipment operating efficiently including repair/replacement of malfunctioning equipment.
- **Modifications:** Changes made to the plant or plant systems to improve operations and efficiency or to reduce costs.
- **Decontamination:** Work performed to remove radioactive contamination from areas, equipment, and tools.

In general DAW consists of any solid, dry material that becomes contaminated with radioactive material and is discarded as waste. DAW produced by LWRs typically consists of:

- Plastic (bags, booties, gloves, sheets, etc.)
- Paper
- Wood
- Pipes & Valves
- Used Equipment/Components
- Discarded Tools
- Dirt
- Concrete
- Discarded Protective Clothing
- Ventilation Air Filters, etc.

5.3 WET WASTE SOURCES

The ultimate source of all low-level radwaste generated in a nuclear power plant is the primary coolant system or to a lesser extent the spent fuel pool. Fission and activation products, as well as tritium and small amounts of tramp uranium, migrate throughout the plant and into various liquid streams.

The majority of wet solid wastes generated from nuclear power operations are produced as a direct result of processing contaminated liquid waste streams. Other wet wastes may be generated from the cleanup of leaks and spills, or from the cleanup of sediment from the bottom of tanks and sumps. For convenience, solid wastes that contain sufficient free water to exceed limits for disposal under 10 CFR 61 without processing are termed wet solid wastes.

Wet solid waste typically produced by LWRs includes:

- Spent Ion Exchange Resin (bead or powdered resin)
- Charcoal Media
- Filtration Media (eg., diatomaceous earth)
- Filter Cartridges
- Sludges from the Bottom of Tanks and Sumps

The term "wet wastes" designates contaminated wastes with sufficient water content for pumping to collection tanks for further processing.

The majority of wet solid wastes are generated from liquid waste processing. The relative volume of individual wet waste streams generated by a typical LWR will vary based upon plant operating conditions and processing methods utilized.

5.4 COMPARISON OF PWR AND BWR SOLID RADWASTES

PWR and BWR solid radwastes generally consist of the same types of materials and contain similar radiological characteristics such as a predominance of corrosion products and many of the same radioisotopes. The sources of waste vary because of the difference in plant design.

The relative volumes of the different waste streams vary quite a bit when comparing PWRs with BWRs. In general, the average BWR unit generates approximately twice as much radwaste as the average PWR unit. BWRs typically generate 50 to 100% more DAW and 200 to 400% more wet solid wastes, based on average disposal volumes for each type of unit. BWR wet waste consists primarily of powdered resin from filter and demineralizers, while PWR wet waste consists primarily of bead resin from deep bed demineralizers.

5.5 A SUMMARY OF LWR SOLID RADWASTES

Solid radwastes generated by LWRs units typically consists of DAW, spent ion exchange resin (primarily bead resin), filters and/or filtration media and miscellaneous liquid/wet solid wastes.

5.6 SOLID RADWASTE PROCESSING SYSTEM

The functions of a solid radwaste system are to collect, process, package and provide interim storage for solid radioactive waste prior to shipment for off-site disposal and to solidify wet or liquid wastes when required for disposal.

The solid radioactive waste processing system begins at the interface with the liquid radioactive waste processing system boundary at the inlets to the following tanks:

- Spent resin
- Filter sludge
- Phase separator

All contaminated materials are processed in the appropriate portions of the solid waste system. These materials include:

- Spent air and liquid filter elements
- Spent bead resins
- Filter sludge
- Spent powdered resins
- Reverse osmosis concentrates
- Dry radioactive wastes

The system terminates at the point of loading the filled containers on a vehicle for shipment off-site to a licensed burial facility.

Many design criteria for the solid waste system are based on regulations, standards and other requirements that dictate the physical characteristics, containerization, radiation levels, etc. Compliance must be achieved with:

- DOT regulations
- Burial facility specifications
- License conditions and requirements
- Site procedures
- State regulations
- Applicable ANSI standards

A more detailed discussion of burial criteria is contained in Chapter 6.

The system design includes provisions for:

- Semi-remote transfer of filled containers to storage
- Maintaining accountability during storage
- Transfer of containers to a shipping carrier
- Proper survey of containers

The radioactive solid waste processing equipment is typically located in a separate building or area within the facility. Both wet and dry solids are processed by these systems.

Solid waste processing technologies at BWRs and PWRs are similar. The primary difference is the tie with liquid radwaste processing and plant systems.

The specific design of solid waste processing systems and the technologies selected vary from facility to facility; therefore, for specific information on a particular facility consult its FSAR and amendments.

It *has become* more common to ship waste in bulk to an off-site sorting and processing facility to achieve optimum volume reduction by a variety of techniques.

This chapter discusses various unit operations and processing technologies used to reduce volume and/or treat solid waste streams to produce a waste form acceptable for disposal.

5.6.1 PWR Solid Waste Processing System

A PWR handles concentrated boric acid solutions and provide different feed from the liquid waste processing system than for a BWR. Unlike BWRs, PWRs do not utilize condensate demineralizers to maintain reactor coolant purity.

5.6.2 BWR Solid Waste Processing System

The primary difference of the solid waste processing system at a BWR is the tie with liquid radwaste processing and plant systems. Figures 5.6-1 and 5.6-2 show the phase separator and the spent resin and waste packaging systems in a typical BWR.

The BWR solid radwaste system is divided into several subsystems so that the solid radwaste from various sources can be collected and processed separately. The phase separator and spent resin handling system collect and process wet wastes. Irradiated reactor components are handled and packaged in the fuel pool.

With the exception of the packaging of irradiated reactor components in the spent fuel pool, all of the solid radwaste system are typically within the Radwaste Building. The Radwaste Building Ventilation system provides proper ventilation of the rooms and equipment.

5.6.2.1 Phase Separator System

The phase separator system consists of:

- Cleanup phase separators
- Condensate and waste phase separators
- Cleanup backwash and receiving tanks
- Waste backwash receiving tank
- Condensate backwash receiving tanks
- Cleanup backwash transfer pumps
- Cleanup decant pumps
- Cleanup sludge pumps
- Waste backwash transfer pumps
- Condensate and waste backwash transfer pumps
- Condensate and waste decant pumps
- Condensate and waste sludge pumps
- Associated valves, piping and instrumentation

The phase separator tanks accumulate and store spent powdered ion exchange resin and filter sludge, which are pumped into the tank as slurry in batches. The solids are allowed to settle and the supernatant liquid is decanted to maintain capacity for subsequent batches of slurry. This process is repeated until the solids reach a prescribed level in the tank. They are allowed to decay for an appropriate period before they are reslurried and pumped to the packaging facility.

Cleanup phase separator tanks collect the high-activity sludge from the reactor water cleanup system.

The condensate phase separator tanks store sludge from the condensate and the fuel pool filter-demineralizers and from the waste and floor drain filters.

Expendable filter/demineralizer ion exchange resin and filter precoat are removed when necessary by backwashing the filter/demineralizer or filter unit.

The backwash receiving tanks collect the cleanup and condensate filter/demineralizer systems' sludges. The sludges are then fed to respective phase separators where excess backwash water is decanted to the waste collector tank and the sludge is accumulated.

The fuel pool filter/demineralizers, waste collector filter and the floor drain filter are backwashed to the waste backwash receiving tank. From there the sludges are fed to the condensate and waste phase separators.

5.6.3 Wet Solid Wastes

Wet solid wastes consist primarily of:

- Spent demineralizer resins
- Cartridge filter elements
- Filter sludges.

The processing of wet solid wastes and dewatering of liquid radwaste are performed remotely from behind shielded walls. The processes are observed through viewing windows or via a video system. Areas used to solidify and process solid wastes are often maintained under a slight negative pressure differential to ensure any leakage is in-leakage.

5.6.3.1 Spent Demineralizer Resins

Spent Resins are sluiced to a large spent resin storage tank by the resin transfer system. The water level in the spent resin storage tank is always maintained above the actual level of the spent resins, thus keeping the tank inert. The volume of resin in the tank is known from a record of resins sluiced to and from the tank.

5.6.3.2 Cartridge Filter Processing

Cartridge filters consist of cellulose type elements placed within a stainless steel cage assembly. An exhausted filter is removed from its vessel using long handled tools and hoisted into a shielded container and transported to the waste solidification area. Filters are carefully placed in shipping containers and surrounded by the solidification matrix.

5.6.4 Volume Reduction

Typical volume reduction techniques that are representative of practices used throughout the industry include:

- Resin dewatering and drying
- Compaction and Supercompaction
- DAW Incineration
- Material Decontamination

This list does not include all available processing methods.

5.6.5 Dewatering of Wet Solids

One of the most common methods currently used throughout the nuclear industry for treating resins and sludges prior to disposal is dewatering. The dewatering process pumps excess liquids from the waste by suction of the liquids from the container of waste back to the liquid waste processing system.

Dewatering of resins usually is accomplished in two steps. The first step involves a holdup phase where resins or sludges are allowed to settle to the bottom of a tank or phase separator and then excess water is decanted from the top. The result of this first step is a more concentrated slurry, which is pumped into a process vessel or disposal container for final dewatering. This second step involves the drawing of excess liquid from the container via suction.

Containers used for dewatering processes are equipped with dewatering laterals. These tree-like structures contain filter "arms" of variable micron rating (depending on the waste stream) that extend throughout the container for maximum surface contact with the waste slurry. Liquids are drawn through the laterals, up and out of the container and into a liquid waste holdup tank for further processing. When the dewatering process is complete, the laterals remain inside the disposal container, which is a High Integrity Container (HIC), and are buried with the waste.

Some process vendors offer variations of the basic dewatering process. These enhancements include thermal cycling of the waste slurry using blowers to achieve a drier and more volume efficient waste product. Another technique used with dewatering is to place the entire disposal container under negative pressure (i.e., in a vacuum). This forces liquids from the container while compressing the resins/sludges into a more volume efficient product.

Dewatered wastes requiring stability (Class B and C wastes) must be packaged in HICs that meet the requirements of 10 CFR Part 61.56. In accordance with these regulations, dewatered containers shall not contain more than 1% free standing liquid by volume. Therefore, process control programs (PCP) must be developed for different waste streams to ensure regulatory compliance of the final waste form.

5.6.5.1 Resin Drying

Dewatering techniques incorporate thermal cycling of resins for better drying and more efficient packaging of resins.

5.6.5.2 Potential Problems

Some potential problems that must be identified and addressed during the full scale testing of the PCP are:

- Plugging of laterals
- Elimination of all free water
- Channelling of liquid

If the filters for the dewatering laterals are not properly sized for the waste stream, plugging can occur. The potential for plugging increases with decreased particle size in the waste stream.

If suction from the dewater laterals is not uniformly applied to the waste, some areas are not properly dewatered. To ensure compliance with waste form requirements of 10 CFR Part 61, verification that free standing liquids are less than 1% by volume must be supported by a detailed Process Control Program (PCP), which addresses all process parameters and is verified by full scale testing.

5.6.6 Compaction and Supercompaction

Compaction and supercompaction are processes used in the nuclear power industry to volume reduce dry active wastes by removing air spaces from the material via compressive forces. Utilities generally use an off-site processor.

The primary difference between compaction and supercompaction is the compressive forces used to compact the wastes. Compaction forces typically found in supercompactors designed for drums range from 1,500 to 2,200 metric tons of force. Volume reduction factors of 2:1 over normal compaction can be achieved.

Many plants use off site supercompaction services provided by vendors. The trend is to ship waste off site in bulk in boxes or sea land containers for supercompaction. This eliminates handling and processing requirements at the plant and assists the waste processor.

5.6.7 DAW Incineration

A significant percentage of the DAW generated by LWRs is combustible materials (plastic, paper, cloth, wood). Incineration is a process that reduces radwaste volumes through conversion of bulk contaminated materials into radioactive ash and residue. Volume reduction (VR) factors in excess of 200:1 (relative to bulk waste volumes) can be achieved. Actual VR factors vary based upon off-gas processing, ash processing, and waste feed.

An incineration system for processing radioactive waste typically consists of:

- Waste preparation and loading area
- One or more combustion chambers
- Off-gas treatment system
- Ash unloading equipment
- Ash processing equipment
- Instrumentation and controls

Waste is typically shipped for incineration in bulk to aid in sorting and segregation prior to incineration.

5.6.7.1 Potential Problems

Problems experienced with incineration include:

- Acidic gases
- Incomplete combustion
- Crud traps
- Solidification of ash

Acidic gases, produced from the combustion of PVC and rubber products, can cause corrosion in the incinerator chamber and off-gas system. Wet scrubbing off-gas systems can be used to process these gases; however, the resultant scrubbing solutions must be solidified for disposal.

As the proportion of materials that produce acidic off gases increase, the volume of scrubbing solutions also increases, the volume reduction efficiencies are lowered. Replacement of PVC and rubber items with alternative materials usually alleviates this problem. Careful consideration must be given to the composition of the waste stream to make the incineration process both volume and cost effective.

Incineration efficiencies are related to the heating value of the waste feed materials. Waste feed rates must be adjusted based on the feed materials. Items with a low heating value can be fed at a relatively fast rate but might require additional fuel for complete combustion. On the other hand, materials with a high heating value must be fed at a slow rate, thus reducing incinerator processing rates.

In addition to heating value, any noncombustibles that enter the incinerator could jam or damage the ash handling system as well as reduce overall processing efficiencies.

Ash is typically pushed through the combustion chamber and into the ash handling system by way of a ram device. These devices are not 100% effective at clearing all ash from the combustion chamber and some ash accumulates, resulting in activity buildup and ALARA concerns over time.

Disposal sites require the solidification of ash prior to disposal due to the dispersibility of the waste form. The ratio of solidification agents to ash that is necessary to comply with disposal site requirements affects the overall volume reduction efficiencies of the process system.

5.6.8 Material Decontamination

This processing technique can involve off site services or on site processing to decontaminate equipment, large components, etc.

Decontamination processes include:

- Abrasive blasting techniques
- Chemical cleaning solvents
- High pressure sprays
- Electropolishing

They remove the layer of contamination from the surface of objects.

Following successful decontamination, materials are frisked to check for contamination and then released as clean material.

Attachments 5-1 through 5-5 show several commercially available options for the treatment and disposal of solid wastes.

5.7 SOLID RADWASTE MANAGEMENT PRACTICES

Solid radioactive wastes are generated during the operation and maintenance of a LWR. The radioisotopic, chemical, and physical compositions of these waste materials vary from source to source. Moreover, efforts to control the volume of solid radwaste subject to burial at licensed LLW facilities are subject to a number of regulations and regulatory guidelines.

Solid radwaste management practices can be effective throughout the following stages of the radwaste process:

- Generation
- Processing
- Packaging
- Handling
- Storage
- Shipment
- Disposal

5.7.1 Control of Radwaste Generation

To establish and implement effective solid radwaste management controls at any of the above stages without unwarranted compromise of other important goals, requires a clear understanding of impacts of any proposed solid waste management action on the plant overall. Most nuclear power

plants have adopted and maintain management goals for their radiological protection programs. These goals include and are interrelated with solid waste management. Among other objectives, the goals are designed to:

- Minimize radwaste disposal volume
- Control generation of radioactive waste
- Minimize the spread of radioactive contamination
- Maintain personnel exposure ALARA
- Ensure compliance with all applicable regulatory requirements.

In some instances, action to achieve one goal has a positive impact on another goal. However, most of the simple actions of this nature have been institutionalized by the industry. Some of these actions are listed and discussed below. Other actions to achieve one goal are antagonistic to another goal. For example, some actions that are beneficial to waste minimization efforts are antagonistic to worker exposure. Attempts to eliminate one type of waste can create other types of waste.

Some relationships are not in temporal phase. What is desirable for a specific short term goal may be contrary to longer term goals, and vice versa. A carefully planned balance is required to optimize practices to implement these goals. Strong management commitment is vital to programs such as radwaste minimization. When there is competition for resources and a need to establish priorities, management input is required to aid in arriving at good objective decisions.

A number of typical examples in controlling generation of radwaste are discussed below. There are a number of variations to each of these and the list is not all inclusive. Nevertheless, it serves as an example of the kinds of steps that can and are being taken to reduce radioactive waste.

A key objective of generation control is to eliminate any unnecessary or unwarranted sources of solid radwaste. Typical actions instituted to accomplish this are:

- Identification of waste sources
- Worker awareness programs
- Controlled/contaminated area material/ personnel entry restrictions
- Job pre-planning
- Tool/equipment staging/control
- Spill/leak reduction and control
- Contaminated area minimization
- Process stream protection
- Housekeeping programs
- Material segregation
- Decontamination programs
- Adoption of reusable materials
- Special/expanded material storage facilities

5.7.1.1 Identification of Waste Sources

On-going identification of the nature, extent and sources of major contributors to radwaste is fundamental to ensuring that the most effective actions are implemented at any stage of the waste cycle. In some cases, it is as simple as controlling work practices to preclude unnecessary

radwaste generation; in others it requires sophisticated analysis and planning to overcome fundamental problems associated with existing methods of radwaste handling. One example of this is finding suitable alternatives to cement solidification.

5.7.1.2 Awareness training

Training and awareness are important factors in a volume minimization program. Better work habits and an understanding of radiological conditions help workers control radwaste generation.

5.7.1.3 Area Decontamination

Cleaning contaminated areas within the plant and preventing recontamination of the area allows more work to be performed in anti-c clothing and reduces contamination of materials, tools, and equipment. Contaminated areas are prioritized for cleanup based on contamination levels, potential for recontamination, typical access needs, general area traffic, location within the plant, etc. Initially the areas are decontaminated using a wide range of techniques and then they are maintained radiologically clean through leakage control, work planning and good operating and maintenance practices.

5.7.1.4 Reusable Materials

Reusable material, such as washable shoe covers, dedicated hoses/tools/equipment, reusable scaffolding, etc., are used in lieu of disposable materials.

5.7.1.5 Leak Reduction and Control

The institution of a comprehensive leak reduction and control program minimizes leakage and thereby reduces contaminated areas and the generation of radwaste in the plant. Plants have also experimented with valve packings to minimize leaks, and have instituted a priority system to repair leaks in a timely manner. Leaks that are identified are contained and routed to appropriate drains.

Wet solid wastes have been reduced through comprehensive leak reduction programs. For example, high conductivity liquids cause premature exhaustion of ion exchange resin. By controlling leaks high in conductivity, suspended solids, etc., wet solid waste volume is better controlled.

5.7.1.6 Equipment Decontamination

On-site and off-site decontamination services are used by the plant to reclaim rather than disposing of items. Components are decontaminated by various methods either for controlled release for reuse in controlled areas of the plant or for free-release.

5.7.2 Process Controls

A variety of actions are being instituted at the various plants to improve selection of processing options or their implementation. A few examples are:

- Supercompaction
- Off-site incineration
- Dewatering resins rather than solidification

- Segregation of waste streams
- Systematic monitoring and sorting of DAW

5.7.2.1 Supercompaction

DAW collected throughout the plant is visually inspected for tools, equipment, or reusable items prior to being loaded into sea land vans for bulk shipment to an off-site processing facility for supercompaction. Supercompactor densities achieved by the processor typically average 65 pounds per cubic foot, or a volume reduction that is twice that of compaction at the site.

5.7.2.2 Dewater vs. Solidification of Powdex Resin

Powdered resin used in various liquid processing systems was traditionally regenerated. The regenerant waste required stabilization in accordance with 10 CFR 61.55 and 61.56 and disposal site requirements. Solidification of these resins in portland cement results in an overall increase in volume. Plants have switched to dewatering powdered resins in high integrity containers for disposal. This change typically nets a 50% reduction in the overall waste volume.

5.7.2.3 Selective Ion Exchange

Selective ion exchange processes work by removing only certain radionuclides and allowing other ionic species (chemical and radiochemical) to pass through. Average throughput (e.g., gallons processed) has increased significantly with a corresponding reduction in resin generation.

5.8 SOLID RADWASTE PROCESSING

5.8.1 Dewatering Resins

The packaging efficiency for any method of packaging solid particles, with or without the use of solidification agent depends on the physical and chemical interactions between the particles and liquids as well as the achievable spatial relations between the particles and liquids. For simplicity of discussion, the waste particles are considered uniform spheres. Although actual sizes and shapes are quite different, this assumption enables definition of the limiting conditions and helps clarify an otherwise complex situation. In the case of ion exchange resins, both their spatial configuration and their retention of water affect the achievable packaged volume.

Spent ion exchange resins constitute a significant fraction of wet wastes produced at a nuclear power plant. Most plants do not solidify these resins, but ship them in dewatered form.

Dewatering is usually done by pumping excess water from the bottom of the container holding the resin slurry. In some facilities, dewatering of powdered resins is by centrifuge. After such conventional dewatering, most resins still contain a substantial amount of water. This water is held by the resins in three ways. These are:

- Internal absorption
- Adsorption on resin external surfaces
- Encasement in interstices between resins

Suction from the dewatering laterals is not uniformly applied to the waste leaving areas where the waste is not properly dewatered. For tightly packed dewatered resins, it is difficult to distinguish between adsorbed and interstitial water.

The presence or absence of any or all three types of retained water has a significant effect on the dewatered volume.

For example, bead resins typically are about 0.3 to 0.8 mm in diameter, or average of 0.5 mm in a "wet-shipped" state. The pore volume of "wet-shipped" resins is approximately one-half of the total bead volume. The true density of the resin material ranges from 1.0 to 1.25 g/cm³; whereas, the shipping density is about 0.6 to 0.9 g/cm³.

New resins are shipped in a hydrated form in which the internally absorbed water accounts for nearly 50% of its weight. There is little adsorbed surface water and these resins feel dry. They are loosely packed and contain almost no interstitial water (a random close-packed structure of uniform spheres, which is a good approximation for dewatered resins). About two-thirds of the volume is resin bead and the other third is occupied by interstitial water.

If the void space is filled with liquid about half of the internal volume is liquid and a cubic foot of dewatered resin contains about 20 liters of liquid, even if the surface adsorbed water is negligible. In practice, dewatered resins are usually between 25 and 60% solids (by weight). But this does not imply free-water is present.

When resin beads are dried, they contract. They also contract by 5-15% as their ion exchange capacity is exhausted.

Due to the closure of the Barnwell Disposal facility in July 2008 to wastes from outside the Atlantic Compact, many licensees now must store their dewatered Class B and Class C resin wastes on site. Since water is entrained inside the spent resin beads, over time even a fully dewatered spent resin liner can contain >1% free standing liquids, and must be dewatered again prior to final disposal.

Attachments 5-6 and 5-7 show some commercially available vendor rapid dewatering systems. These systems are more commonly found at BWRs rather than PWRs, as the typical volume of spent resins and waste sludge is greater at BWRs, and thus more timely waste processing is advantageous.

5.9 PROCESS CONTROL PROGRAM

10 CFR 61.56, Waste Characteristics, contains the minimum requirements/characteristics for wastes to be disposed of in shallow land burial. Key requirements include:

- Solid wastes shall contain as little free standing liquid as possible, but in no case more than 1% by volume
- Wastes must not generate toxic gases, vapors or fumes, or be explosive
- Void spaces within the waste must be reduced
- Wastes must have structural stability

Additional guidance on acceptable waste form is provided in the Branch Technical Position, “Technical Position on Waste Form (Rev. 1),” which is included as Attachment 5-8, and the Branch Technical Position on “Final Waste Classification and Waste Form Technical Position Papers (1983),” which is at Attachment 5-9.

Guidance on waste encapsulation and concentration averaging is provided in the Staff Technical position, “Branch technical Position on Concentration Averaging and Encapsulation,” which is Attachment 5-10, *and* SECY-10-0043, “Blending of Low Level Radioactive Waste,” which is Attachment 5-11. It should be noted that following the issuance of SECY-10-0043, the State of Utah Radiation Control Board issued a position statement (April 13, 2010) that the Board was opposed to waste blending when the intent is to alter the waste classification for the purpose of disposal site access at the Clive, UT disposal site owned by EnergySolutions (Attachment 5-12). A discussion on waste blending can be found in Chapter 6.

Plant Technical Specifications require that each licensee develop, implement and periodically audit (typically biennially) its Process Control Program (PCP). The PCP is a document which describes the plant processes and equipment that will be utilized to ensure that wastes are prepared for disposal in a form consistent with the requirements of 10 CFR 61.56. The PCP must be submitted to the NRC, and any modifications or revisions to the PCP must also be submitted as part of the annual Radiological Effluent Technical Specification (RETS) report. Attachment 5-13 contains an example PCP. Note that it has general information on the various waste streams present at the facility, along with information on how these various waste streams will be processed to meet the waste acceptance criteria of 10 CFR 61.56.

The NRC inspection program for solid radwaste is found in Inspection Procedure 71124.08, “Radioactive Solid Waste Processing and Radioactive Material Handling, Storage and Disposal,” which is at Attachment 5-14. Key areas for inspection include:

- Review of audits and surveillances conducted as part of the quality control program to ensure compliance with 10 CFR 61.56
- Review of effectiveness of licensee controls in the area of processing Low-Level Radioactive Waste
- Review the qualifications and training of radwaste personnel (see Attachment 5-15, NRC IE Bulletin 79-19)
- Review of licensee’s guidance on waste form and classification, especially the use of scaling factors

Attachment 5-16 provides a facility description, as found in the Updated Final Safety Analysis Report (UFSAR), for a sample BWR site.

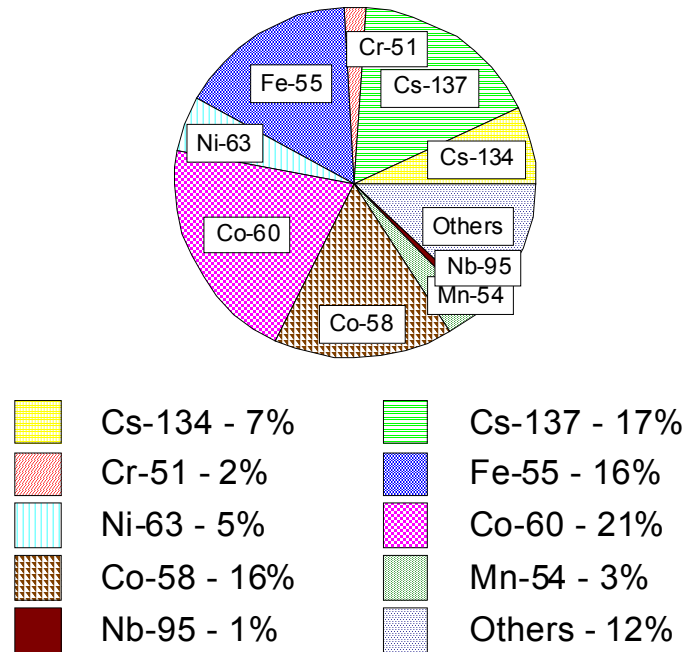
Percent	Description of Waste
31.6	Plastic Bags
19.8	Paper Coveralls
17.9	Plastic Booties
14.5	Various Commercial Plastic Sheeting
6.3	Misc. Paper, Rope, Smears, Tape, Cotton Liners, Face Shields
5.2	Masslin Cloth, Paper Towels
3.2	Recoverable Items, Protective Clothing
1	Mop Heads
Source: EPRI Report T-104583	

Table 5.1-1 Examples of Constituents of DAW

Isotope	PWR Compacted	PWR Non-Compacted	BWR Compacted	BWR Non-Compacted
Cs-137	17	18	9	11
Cs-134	7	7	3	3
Co-60	21	22	37	35
Co-58	16	15	3	3
Mn-54	3	3	7	7
Nb-95	1	1	-	-
Ni-63	5	6	-	-
Fe-55	16	13	19	19
Fe-59			2	2
Cr-51	2	2	5	5
Zn-65			12	12
Others	12	13	3	3

Table 5.1-2 Isotopic Distribution of Dry Active Waste (DAW) in PWRs and BWRs

PWR Compacted DAW



BWR Compacted DAW

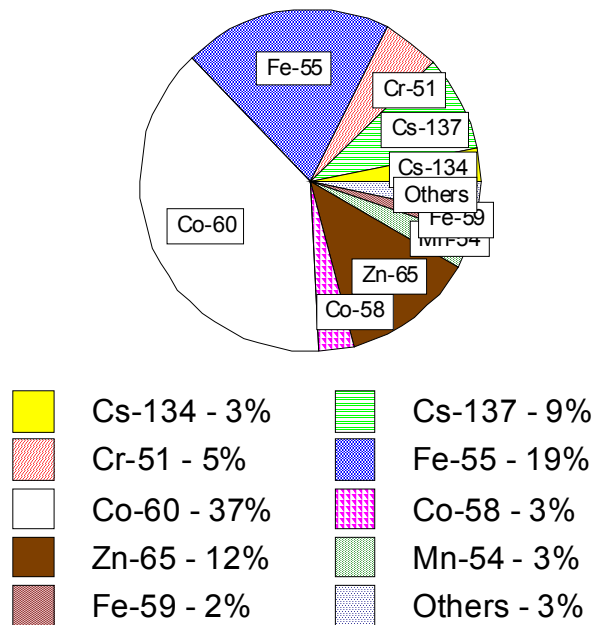


Figure 5.1-1 Isotopic Distribution of Compacted DAW

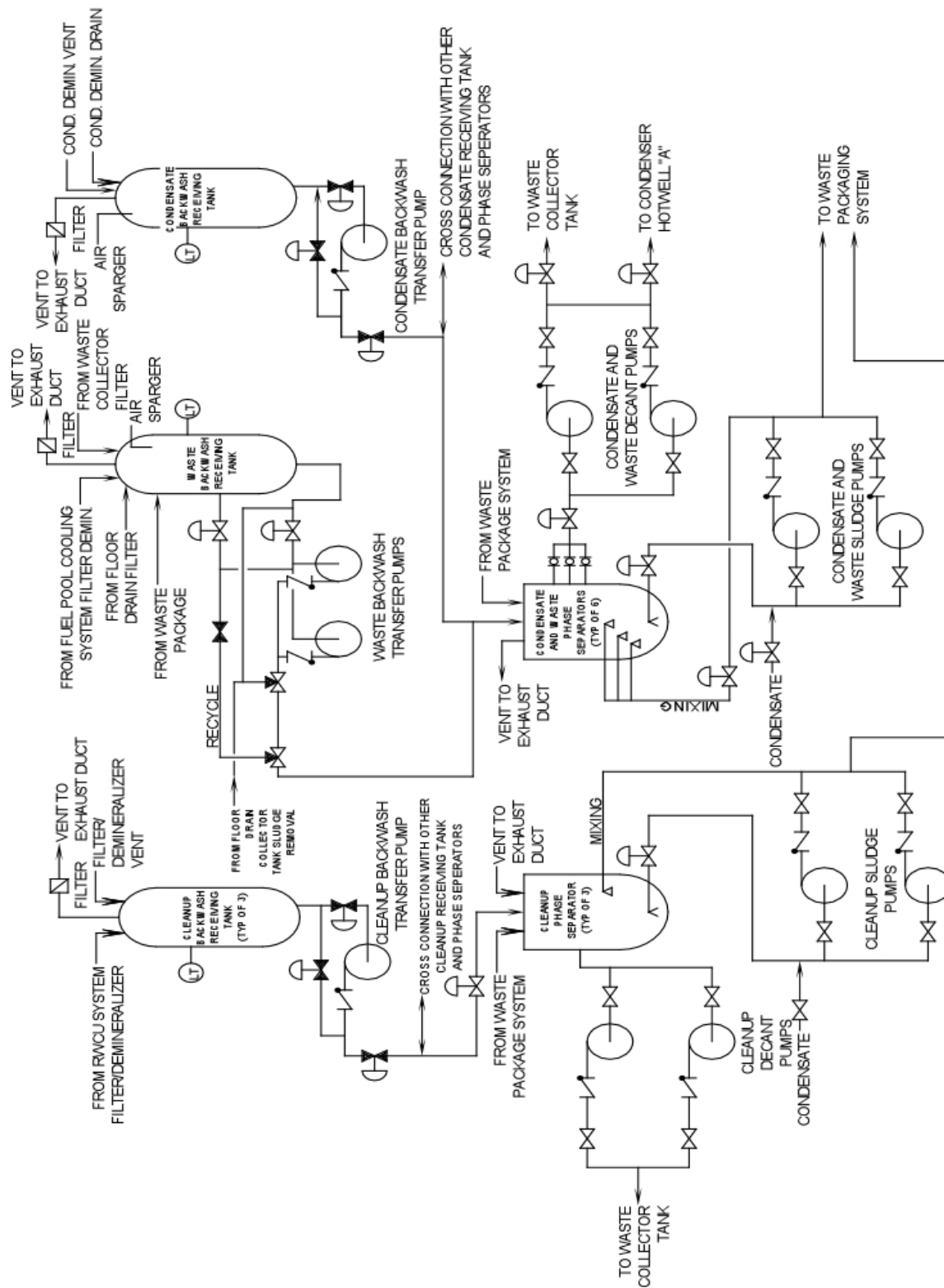


Figure 5.6-1 BWR Phase Separator System

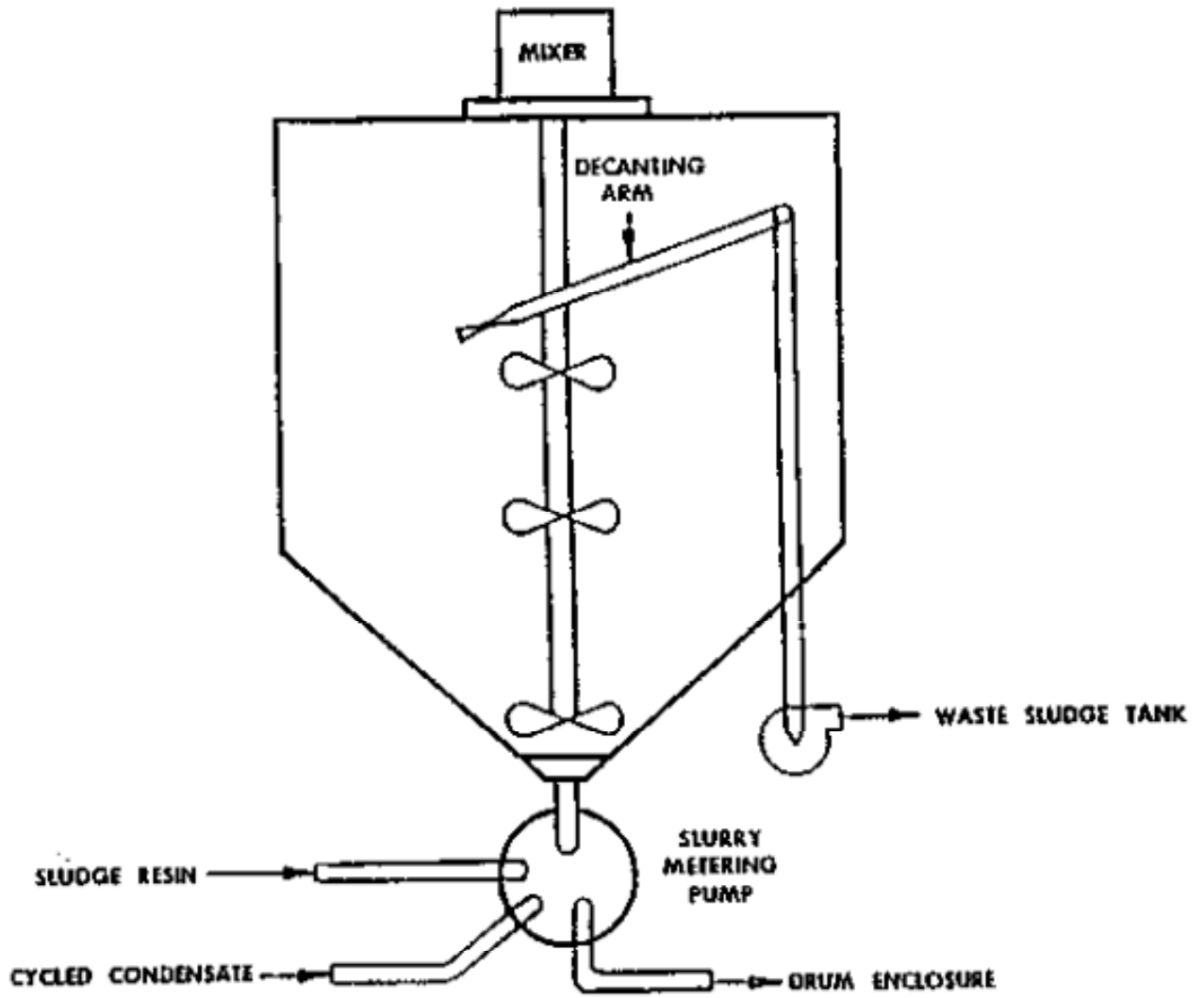


Figure 5.6-2 Decanting Tank

(Intentionally Blank)

Chapter 5

Attachments 5-1 through 5-7

NOTE: Attachments 5-1 through 5-7 include information from vendor brochures and websites for training purposes. The information includes descriptions of products and services offered, but is not a comprehensive list of the available services or contractors that provide such services.

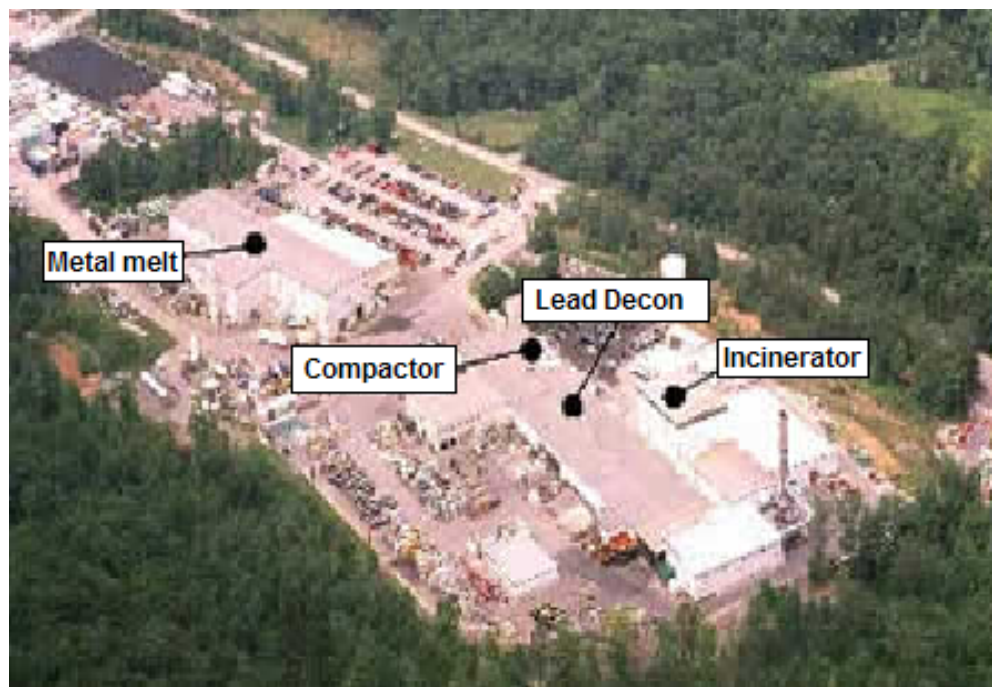
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Off-Site Waste Processing Services Offered by *EnergySolutions*

EnergySolutions offers the most diverse capabilities in the United States for handling and processing radioactive materials. We have the highest waste processing capacity of any U.S. processor, providing efficient processing and disposal for our customers.

EnergySolutions has six processing facilities in Tennessee, South Carolina, and Utah to handle your radioactive material safely, securely and economically. In addition to our Bear Creek facility (see below), we also operate another specialized waste processing facility nearby on Gallaher Road, a large component dispositioning and storage facility in Memphis, Tennessee, our Barnwell Processing Facility (BPF) and Nuclear Services Support Facility, near Barnwell, South Carolina, and the processing facility located at the disposal site in Clive, Utah.

1. BEAR CREEK FACILITY - *EnergySolutions*' Bear Creek facility is located near Oak Ridge, Tennessee. The Bear Creek facility is the nation's largest licensed commercial LLRW (Low-Level Radioactive Waste) processing facility and offers innovative technologies for radioactive material volume reduction including smelting incineration and compaction up to 200 to 1 volume reduction.



Material Disposition

EnergySolutions properly disposes all materials after processing. Options include licensed disposal facilities and state-approved and regulated landfills. We are also uniquely capable of melting metals for beneficial reuse as shielding at Department of Energy (DOE) and other nuclear-

related facilities. For more than 15 years *EnergySolutions'* Bear Creek facility has used a patented metal melting process to provide this service to the nuclear energy industry and other organizations. A 20-ton, coreless induction furnace is used to melt the material before being poured into blocked forms for controlled reuse, most often in high-energy physics projects. This provides a cost-effective alternative to disposal, assisting in the preservation of valuable low-level waste disposal space.

Best Way Processing at Bear Creek

EnergySolutions offers our clients the ability to combine DAW and metals into a single shipment, thus reducing on-site segregation costs and personnel radiation exposure. Materials are sorted at our specially designed sorting facility to direct the waste to the most cost-effective processing methodology. This can include decontamination, incineration, compaction, metal melting for controlled reuse, or repackaging for disposal.

2. MEMPHIS FACILITY - Our licensed 240,000 square foot (22,300 m²) Memphis facility is specifically designed to handle large components such as steam generators, turbine rotors, heat exchangers, large tanks, and similar components. *EnergySolutions* has configured this facility to safely, efficiently, and effectively decontaminate, segment, and disposition radioactively contaminated components.

We offer an extremely cost-effective alternative to direct disposal. Rail, barge, and truck transportation modes can be used to transport items to our Memphis facility. Following segmentation in Memphis, metals can be directly disposed or sent to *EnergySolutions'* Bear Creek Operations for subsequent and beneficial re-use as shield blocks for specific Department of Energy projects.



Steam generators en route to Memphis for segmentation prior to disposal.

Hot Shop Support

The Memphis facility also supports clients' needs for radiological hot shop work. We offer to our clients lease space for the refurbishment and repair of equipment.

Equipment Storage

Memphis also has lease space for storage of radioactive and non contaminated equipment. We offer preventative maintenance and quality control of your equipment. Our record for immediately delivering equipment upon request is impeccable.

3. BARNWELL PROCESSING FACILITY (BPF) - *EnergySolutions'* processing facility located in Barnwell, South Carolina, consists of two pre-stressed concrete buildings and includes 27,000 square feet (2,500 m²) of enclosed space and 15 acres of secure, fenced area. BPF safely disposes radioactive materials through:



- sorting and segregating
- dewatering/disinfecting
- decontaminating
- solidifying/stabilizing
- compacting

The facility maintains contamination control through negative pressure, HEPA-ventilated, climate-controlled buildings. BPF maintains an 80-ton overhead bridge crane for oversized materials and access to the facility via highway and rail.

BPF is licensed for a broad range of radioactive materials under the South Carolina Department of Health and Environmental Control radioactive materials license number 287-04.

4. Nuclear Support Services Facility (NSSF) - The NSSF is a 5,760 sq ft facility used for the refurbishment of Liquid Waste Processing (LWP), Fuel Pool Services and some customer-related field equipment. The NSSF is located within the fenced area of the Barnwell Facility. The pre-stressed concrete building is equipped with monitored negative air flow in both large truck bays and several smaller work spaces, for strict control of contamination.

5. Gallaher Rd. Facility - *EnergySolutions* operates a licensed 240,000-square foot facility at our Gallaher Road location in Kingston, TN to provide Green Is Clean (GIC) assay and disposal and other specialty services for the nuclear industry. The facility includes 113,621 square feet (10,555 m²) of bonded radioactive material storage space. The Gallaher Road location offers

- GIC assay and disposition
- resin drying/dewatering
- alpha waste sorting
- container storage
- equipment storage
- filter processing
- sludge processing
- waste repackaging
- container refurbishment



Sealed Source Encapsulation

We provide concrete encapsulation of sealed sources to meet the appropriate Barnwell, South Carolina; Tooele, Utah; or Richland, Washington, disposal site criteria. Sources are repackaged in appropriate containers, encapsulated in 2500 psi structural concrete, and transported for disposal. *EnergySolutions* obtains all regulatory-required approvals for the respective disposal facility.

Resin Transfer and Dewatering

EnergySolutions provides turnkey services for the transfer, containerization, and dewatering of filter media, resins, and sludges. We use specialized dewatering systems and trained personnel to provide complete assurance that all waste is processed and packaged to meet the stringent disposal site requirements.

High Activity Sludge Processing and Solidification

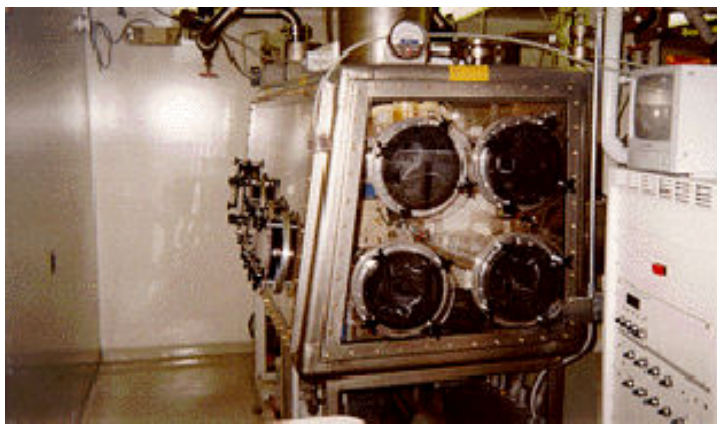
EnergySolutions provides turnkey services for processing and solidification of high activity sump and tank sludges. This service includes consolidation of sludges into appropriately sized containers, including high integrity containers (HICs) as appropriate, solidification, and disposal. We also offer shielded storage and processing capabilities to minimize personnel exposure when handling these high activity sludges.

Specialty Containers

EnergySolutions provides specialty containers including reusable resin liners and boxes with dewatering capability. The reusable resin liners contain a unique dewatering system that reduces resin removal time, facilitates easy refurbishment, and subsequently reduces exposure during resin removal operations. This unique design also reduces life cycle costs for resin containers since the container can be reused many times. For lower activity waste streams, *EnergySolutions* also provides various sized boxes equipped with dewatering capability to remove residual or free standing liquids when boxes are the preferred packaging. We send hundreds of containers to our clients each month for safe storage and transport of radioactive materials.

Glovebox Dismantlement

EnergySolutions can process and dispose of gloveboxes that contain lead shielding. We have successfully dismantled gloveboxes by removing the lead shielding, decontaminating and recycling the lead, and reducing the remaining glovebox components.



Alpha Waste Sorting and Repackaging

EnergySolutions operates a complete sorting and repackaging facility for alpha-contaminated wastes at the Gallaher Road location. This facility is equipped with appropriate containment and ventilation controls to enable sorting and repackaging of waste containing transuranic (TRU) contaminants while protecting personnel. This facility is uniquely configured to sort and inspect contents to ensure that waste meets appropriate disposal site certification criteria.

6. Clive, Utah Facility - Our facility in Utah can provide processing services to treat complex waste management problems before disposal. The Vacuum Thermal Desorption process separates volatile hazardous contaminants from radioactive waste. *EnergySolutions'* encapsulation technology allows us to dispose of large debris and radioactive lead solids up to 25 ft x 16 ft. or small particulate matter.



Arial view of the EnergySolutions' waste processing and disposal site in Clive, Utah.

Our decontamination facility in Clive can eliminate contamination on shipping containers for re-use. The Clive site is located 80 miles west of Salt Lake City and is licensed by the State of Utah for Class A waste only.

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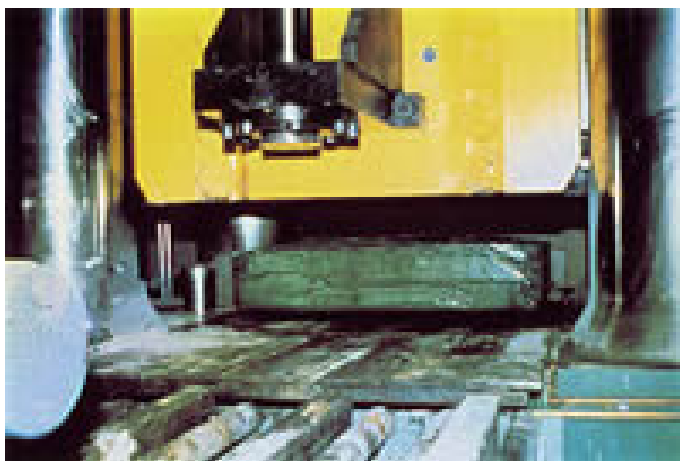
Compaction Services Provided by *EnergySolutions*

EnergySolutions owns and operates the world's largest commercial supercompactor available for dry active waste (DAW) processing. The UltraCompactorT routinely volume reduces DAW by a factor of 6 to 1 and is capable of compacting 14 million pounds of material per month. The UltraCompactorT can compact material in standard drums and in special 38 ft boxes that provide 22 percent better disposal efficiency. In addition to DAW and asbestos, we can volume reduce wastes that would otherwise require more disposal volume such as

- soils
- motors
- pumps
- pipes
- valves
- conduit



Since 1986, the UltraCompactorT has processed more than 125 million pounds of LLRW.



Left: With a force of 10 million pounds, EnergySolutions' UltraCompactorT can achieve volume reductions of 6:1 for DAW and 8:1 for asbestos. **Right:** Both B-25 boxes and 55-gallon drums can be compacted.

Compaction at the Clive, UT Facility

As part of waste preparation for macro vaults at our Clive facility, the operators use a drum compactor as a means of reducing the overall volume of a 55-gallon drum and removing internal voids from the drum. The compactor generates 30,000 lbs of compaction force via hydraulic pressure. The compaction unit has an internal volume of approximately 20Ft³ and is attached to a 2000 Ft³/min HEPA filtration unit providing a high negative pressure to remove all airborne activity that may be discharged from the drum during the compaction process.

The average 55-gallon drum is reduced to approximately 12 inches in height. By using the compaction unit for 55-gallon drums that arrive at the Mixed Waste facility we are able to reduce the overall volume of the waste that is placed in the Mixed Waste embankment optimizing the overall efficiency of the Macro-encapsulation process.



Above: Drum is shown before and after compaction

Incineration Services from *EnergySolutions*

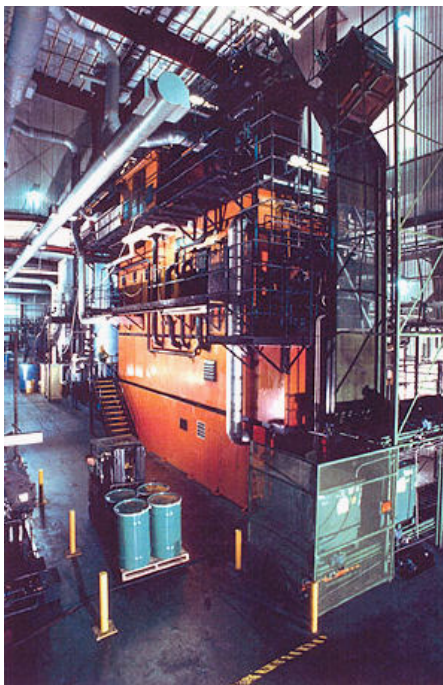
EnergySolutions operates the only licensed commercial radioactive waste processing incinerators in the U.S. These incinerators effectively volume reduce dry active wastes (DAW), non-hazardous waste oils, and other liquids. Incineration is often the most cost-effective process for DAW and is the choice of many of our clients for non-hazardous waste oil and liquids.

Since 1989, more than 3.5 million cubic feet of contaminated waste has been incinerated for clients that include:

Commercial power plants
Department of Energy
Department of Defense
Universities
Government laboratories
Other research facilities



With incineration, typical volume reduction ratios are 200:1



With *EnergySolutions'* incinerators, customers achieve maximum volume reduction of their low-level radioactive waste. *EnergySolutions'* incinerators apply innovative, integrated technologies in treating waste.

Left: One of EnergySolutions' two incinerators, as seen from the control room.

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Metal Recycling Services from *EnergySolutions*

Simply disposing of radioactively contaminated metals is expensive, and only increases the amount of hazardous waste material at existing disposal facilities. But **recycling** metals and lead not only eliminates it from the generator, but allows generators to dispose of other non re-usable material in its stead.

Located at our Bear Creek facility in Oak Ridge, Tennessee, *EnergySolutions*' 20-ton, coreless induction furnace is the largest unit in the U.S. for melting radioactively contaminated metal. The melter is capable of processing 48 million pounds of metal each year. The furnace melts low-activity ferrous metals over a broad alloy spectrum into shield blocks for controlled reuse - most often in high-energy physics projects. Additionally, NO waste is returned to the generator. The small amount of unusable material is disposed of by *EnergySolutions*, as *EnergySolutions*' waste.

Ferrous metals accepted at our facilities for melting are reused and will not enter public metals recycling programs.

This recycling process brings major benefits by eliminating liability for the generator and associated burial costs.



Left: After metal has been approved and sorted, it is placed in the furnace with a magnet or remote-handled. **Right:** After the pieces have been completely melted, it is poured into shield block forms.

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Tank Cleaning and Disposal Services from *EnergySolutions*



After processing more than 1,000,000 ft³ of solidified, dewatered, and thermally reduced waste, we have developed a complete toolbox of effective, proprietary cleaning equipment and techniques that allow us to tailor our cleaning method to your tank's particular conditions and design. All *EnergySolutions'* equipment and techniques have been approved through an extensive process hazards analysis (PHA), ensuring the project is performed in a safe and proper manner.

Seamless Services Save Time and Money

EnergySolutions' turnkey tank cleaning services offers numerous advantages:



- Single point-of-contact for all radwaste products and services
- Comprehensive project management
- Engineering services
- Hazardous waste evaluation and treatment
- Regulatory, waste characterization, and acceptance assistance
- ALARA planning assistance
- Waste removal and transfer
- Internal cleaning and remote video recorded inspections
- Waste packaging services
- Transportation services
- Off-site processing and disposal

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Rapid Dewatering System - RDS-1000™ from *EnergySolutions*

EnergySolutions' RDS-1000™ technology provides our customers with the ability to:

- dry virtually any material
- minimize dewatering times
- efficiently dewater all granular material
- provide superior volume reduction

RDS-1000™ provides a flexible operation with continuous, reliable service. Its compact modular design requires minimal site interface and ease of compatibility. The RDS-1000™ is designed to be compatible with *EnergySolutions'* disposable containers. Its remote operation and system design promotes ALARA, reducing exposure through:

- continuous remote visual container monitoring
- piping designed to reduce crud traps
- internally installed HEPA
- complete remote operation
- remote fillhead removal



RDS System components

RDS-1000™ is designed for easy setup and operation, requiring only one technician for routine operations. And has a topical report approved by the NRC.



HVV™ Dewatering

Until now, the nuclear industry had two types of dewatering systems: those that were complex and expensive, and those that were simple, but of questionable value in meeting disposal site Free-Standing Water (FSW) requirements.

Today, DTS gives you a third and superior choice – a system that incorporates the assured regulatory compliance of the big "super suckers" with the economy and simplicity of "pump-and-wait" dewatering.

Our High Velocity Vacuum (HVV™) Dewatering System uses a vacuum to remove residual FSW from a disposal liner.

Why HVV™ Works

The Old Way

The air-operated diaphragm (AOD) pumps used for "pump-and-wait" dewatering draw a high vacuum, but a low volume of air.

Water that collects in and around dewatering internals is pulled s-l-o-w-l-y into the dewatering piping. This low volume of air is not enough to pull the water *up* and *out* of the piping unless there is a water seal on the internals. When his seal is broken (with many gallons of liquid remaining in the container) the water drops back down the piping into the container.

The HVV™ Way

In contrast, the HVV™ pulls a high volume of air through the internals.

This powerful vacuuming action pulls any water near the internals into the piping and sweeps it out of the container the same way a shop vacuum sucks water off the floor. An AOD pump given the same task would fail – as it does trying to remove the last 20 to 40 gallons of water from a disposal liner.



HVV™ Fillhead with Camera

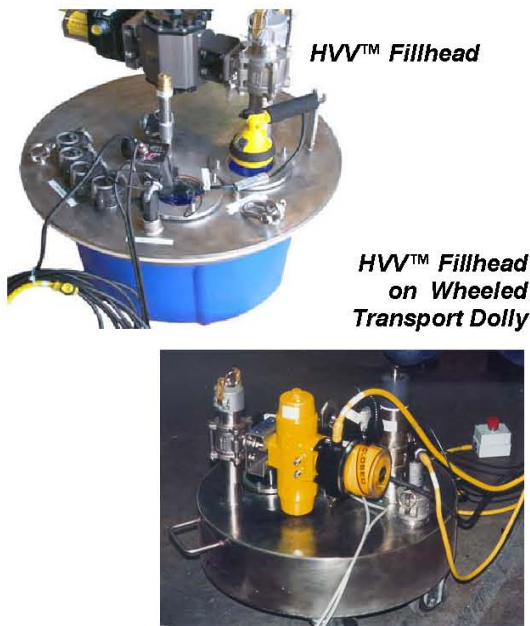


HVV™ Control Skid

Optional Fillhead

While the HVV™ is designed to operate without a liner fillhead, an optional automatic fillhead adds extra control and convenience. It includes:

- color camera and light source
- influent/effluent connection ports
- sluice isolation valve
- thermal monitor
- electronic level monitor
- lifting device (removable lifting post attaches in center of fillhead)
- wheeled transport dolly



HVV™ Fillhead

**HVV™ Fillhead
on Wheeled
Transport Dolly**

This fillhead mates to the HVV™, or can be used as a "stand-alone" for transferring material to containers.

When the electronic level monitor senses that water/resin has risen to a predetermined point in the container, a pneumatic influent valve automatically closes. This valve can also be actuated with a hand-held pendant. With loss of air or power, the sluice valve actuates to a fail-safe closed mode.

The fillhead's remote and automatic features help reduce exposure to ALARA by making it easy for personnel at a distance from the dewatered liner to monitor and operate the unit.

Dewatering Time

Liners are ready to ship by the second day of HVV™ dewatering.

Elegant Simplicity

This single-unit vacuum has no complicated controls, control panels, blowers, heaters, rheostats, condensers, chillers or other equipment; just an ON/OFF switch. Such simple design makes the HVV™ System reliable and almost maintenance-free.

Compatibility

The basic HVV™ System, dewatering internals, and optional fillhead are compatible with any steel liner or High Integrity Container (HIC) used by the nuclear industry today.

The optional fillhead can be used with the DTS Vinyl Ester Resin In Situ (VERI™) polymer solidification process.

Regulatory Compliance

To assure compliance with disposal site FSW requirements, DTS performed extensive full-scale testing of the HVV™ with liners up to 200 cubic feet in volume.

After a road test simulating a trip to the disposal site, liners dewatered with the HVV™ were checked for FSW and found to comply with site requirements by a factor of 25 to 50 times.

Data from these tests is available for inclusion in your plant's records.

The HVV™ has been approved by the State of South Carolina Department of Health and Environmental Control (DHEC) for dewatering waste for disposal at Barnwell.



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Chapter 5

Attachments

5-8 through 5-16

