



3.3.5 *ORNL*—Oak Ridge National Laboratory

3.3.6 *PTFE*—Polytetrafluoroethylene

3.3.7 *PVC*—Polyvinyl Chloride

3.3.8 *RFD*—Reverse-Flow Diverter

#### 4. Significance and Use

4.1 Obtaining samples of high-level waste created during the reprocessing of spent nuclear fuels presents unique challenges. Generally, high-level waste is stored in tanks with limited access to decrease the potential for radiation exposure to personnel. Samples must be obtained remotely because of the high radiation dose from the bulk material and the samples; samples require shielding for handling, transport, and storage. The quantity of sample that can be obtained and transported is small due to the hazardous nature of the samples as well as their high radiation dose.

4.2 Many high-level wastes have been treated to remove strontium (Sr) or cesium (Cs), or both, ~~underwent~~ have undergone liquid volume reductions through pumping and forced evaporation or have been pH modified, or both, to decrease corrosion of the tanks. These processes, as well as waste streams added from multiple process plant operations, often resulted in precipitation, and produced multiphase wastes that are heterogeneous. Evaporation of water from waste with significant dissolved salts concentrations has occurred in some tanks due to the high heat load associated with the high-level waste and by pumping and intentional evaporative processing, resulting in the formation of a saltcake or crusts, or both. Organic layers exist in some waste tanks, creating additional heterogeneity in the wastes.

4.3 Many of the sampling systems have limitations including the ability to sample varying depths in the tank and the depth of sampling. Sampling in Hanford tanks is constrained by riser diameter, riser location and riser availability.

4.4 Due to these extraordinary challenges, substantial effort in research and development has been expended to develop techniques to provide grab samples of the contents of the high-level waste tanks. A summary of the primary techniques used to obtain samples from high-level waste tanks is provided in [Table 1](#). These techniques will be summarized in this guideline with the assumption that the tank headspace is adequately ventilated during sampling.

#### 5. Liquid-Only Sampling Techniques

5.1 Liquid only techniques are ~~not common in tank waste sampling. More common are liquid samples sampling at Hanford using the bottle on a string technique. Liquid only samples are also captured by methods used primarily to obtain solid or slurry samples—samples such as core sampling.~~ However, some high-level waste tanks, such as the Highly-Active Storage Tanks (HAST) tanks at Sellafield in the United Kingdom, had sampling systems installed in the tanks before the high-level waste was added. The HAST system uses a needle orifice as part of a Reverse-Flow Diverter (RFD) to obtain samples. The needle orifices are easily plugged by particles; only liquid samples can be obtained by this system. The HAST system design also allows for the agitation of tank contents to help obtain representative liquid samples (2).

#### 6. Slurry/Liquid Sampling Techniques

6.1 The simplest of the liquid sampling techniques is dip sampling. At the Hanford Site, this sampling technique is often referred to as “bottle on a string.” Only liquid or slurry samples can be taken by this method. Samples can be taken at various depths in the tank to determine whether there is vertical heterogeneity in the tank. If data on the stratification in the tank is not needed, waste in the tank should be sparged or mixed before taking the sample to decrease sampling bias.

6.2 A dip sample is taken by lowering a stoppered and weighted bottle into the waste to the desired ~~depth.~~ depth (see Fig. 1). After the bottle has reached the desired level, the stopper is pulled from the bottle and the liquid or slurry sample flows into the bottle. ~~Ideally, the stopper is then closed and the bottle is pulled from the tank-bottle (3).~~ At Hanford the sample bottle is not capped immediately after sampling. Some mixing can occur as the sample is pulled back up through the liquid column.

6.3 Dip sampling is limited to lower viscosity liquid and slurry materials and the effectiveness of sampling is highly dependent upon the size of the sample bottle inlet and the presence of saltcake layers which may prevent sampling access to lower tank levels. Further, sampling locations are limited only to vertical columns directly under a tank penetration, or riser. Particulates obtained from this method may be highly biased due to sample location and variations in settling velocity while sampling.

6.4 Liquid samples from radioactive-waste tanks have also been obtained using a vacuum-pump system. Samples were pulled by vacuum from the specified level in the tank through polytetrafluoroethylene (PTFE) tubing into a sample jar; if necessary, the sample jar could be shielded. A stainless-steel pipe nozzle is attached to the bottom of the PTFE tubing to keep it vertical. A diagram of the vacuum-pump sampling system used at Oak Ridge National Laboratory (ORNL) is provided in [Fig. 12](#) (4).

#### 7. Solids/Slurry Sampling Techniques

7.1 Early sampling of the solids content of Hanford tank wastes was by the use of an auger. Auger samples were taken only from the surface of the waste and were limited to 6 in. This 6 in. limitation was driven primarily by a desire to reduce radiation dose. Some homogenization of the sample occurs while obtaining auger samples. These samples can only be taken directly beneath a penetration, or riser (5).

**TABLE 1 High-Level Waste Tank Sampling Methods**

Technique	Material Type			Notes
	Solid	Slurry	Liquid	
HAST in-tank needle orifice			X	Orifice as part of Reverse-Flow Diverter (RFD)
Bottle on a String		X	X	Dip sample
Vacuum Pump		X	X	
Auger	X	X		Only high viscosity slurries
Sample Cup	X	X		Manual system used at Savannah River Site to obtain salt-cake samples and hard sludges that don't slump.
Core Drilling— Rotary Mode (Hanford Sampler)	X	X		Hard sludges and salt-cake.
Core Drilling: Rotary Mode (Hanford Sampler)		X	X	Hard sludges and salt-cake.
Core Drilling— Push Mode (ORNL Soft Sludge Sampler)		X	X	Liquid or soft sludges.
Core Drilling: Push Mode (ORNL Soft Sludge Sampler)		X	X	Liquid or soft sludges.
Off-Riser Sampling System (ORSS crawler)	X	X		Used to collect sludge samples to support tank closure at Hanford.
Cylinder with retractable nose cone		X	X	Used at Savannah River Site for soft sludges and liquids.
Robotic Arm	X	X	X	Material type captured is dependent upon the end-effector.
Robotic Arm	X	X	X	Material type captured is dependent upon the end-effector.
Clamshell Sampler	X	X		Used to collect solids samples at Hanford
Fingertrap Sampler	X	X		Used to collect solids samples at Hanford
Drag Sampler	X	X		Used to collect sludge samples to support tank closure at Hanford.
Hydraulic Mining	X	X	X	
Hydraulic Scoop	X	X	X	
Sample Thief (Bacon Bomb)			X	



FIG. 1 "Bottle on a String" Sampler

7.2 Auger samples are taken by encasing an auger in a shroud to contain the sample. The auger is rotated through the sample while the shroud remains stationary. Sample is collected along the flutes of the auger. Liquid is generally not contained in the auger unless it is associated with solids in the form of a sludge or highly viscous slurry.

7.3 Savannah River Site staff developed a manual method of capturing salt-cake samples from waste tanks. This method incorporates a sample cup pinned to a handle that can be driven into the salt cake. The cup has a sharp edge to allow it to cut through the salt cake as the handle is pounded with a hammer. The bore of the cup has a ledge like a fishhook barb that captures the material once it is forced into the cup. The cup design is shown in Fig. 23 (6). The applicability of this method is limited to hard materials that will not flow or slump once collected in the sample device.

7.4 Core drilling is Historically, core sampling was the primary mechanism for obtaining samples from the Hanford waste tanks. A core-drilling truck with a shielded handler was specifically designed for this purpose. Two modes, push or rotary, can be used to obtain samples. Liquids, slurries, and soft sludges can be obtained in push mode; rotary-mode sampling must be used to obtain samples of harder sludges and salt-cake. Only minimal success has been achieved when sampling saltcake. A new core sampling platform was designed and implemented at Hanford in 2015 called the Modified Core Sampling System. The new system, although based on the existing system is intended to have a number of improvements including but not limited to the following: provide a safer environment for the personnel involved in operation of the equipment, reduced sampling cost and schedule, reduction in size, weight and smaller component configuration of core drill rig that must interface with risers on top of tank and provide the opportunity to minimize in-farm operations with the ability to co-locate support systems outside of the tank farm. Fig. 4a and b shows the core sampling platform, both as a photograph and schematic (7).

7.5 The Hanford Sampler is based on a modified core-drilling design that is similar to the thief-and-trier-type samplers. Details of the core-drilling truck procedure are provided in Waste Characterization Plan for Hanford Site Single-Shell Tanks (78),(89). Liquid and solid samples are trapped in the sampler by a spring-actuated rotary valve (see Fig. 35). Two different sampler designs have been used, but both designs incorporated the spring-actuated rotary valve. The first design produced samples that were 19 in. long and 1 in. in diameter. The later design had a slightly larger diameter (1.25 in.). It is important to note the design length of this sampler was driven by operational space limitations of the existing hot cells at the time. Core samples can be taken at varying depths to obtain samples that comprise the entire depth of the waste. A sliding piston in the sampler controls the height of the sample being collected. A hydrostatic fluid is added via the drill string to keep the waste from slumping into the void created by the sample when the sampler is pulled from the tank. Normal paraffin hydrocarbons (NPH) were initially used as the hydrostatic fluid. Nitrogen gas has also been used.

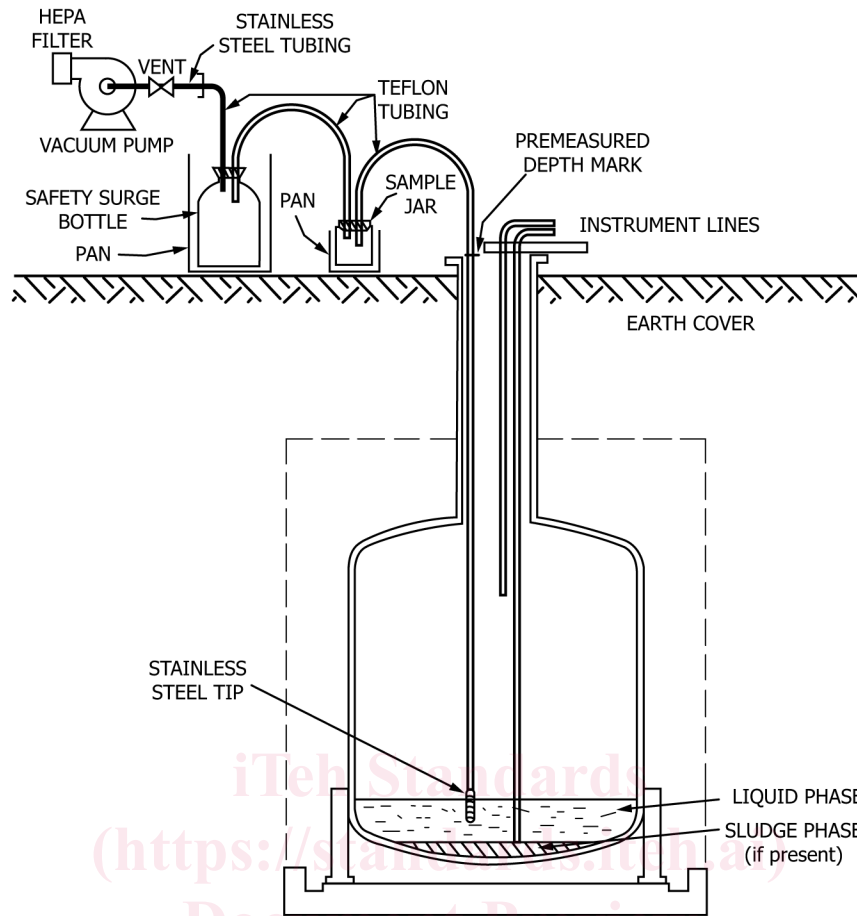


FIG. 42 Vacuum Pump Sampling System

7.6 A sampler based on the same principle was used at ORNL to obtain samples of soft sludges from waste tanks at that site. Samples are collected by manually pushing a polyvinyl chloride (PVC) pipe with a detachable handle assembly into the sludge in the tank. A bottom closure that can be controlled from above by the operator is incorporated into the sampler Fig. 46. This sampler is capable of capturing both liquid and soft sludge samples. A brief description of the operation of this sampler is provided in an ORNL technical document describing the sampling and analysis of radioactive waste tanks (4).

7.7 The Savannah River Site developed a similar method for obtaining soft sludges. The sampler is a cylinder with a retractable nose cone at the bottom. Sections of pipe are added to the sampler to lower it to the desired depth in the tank. Penetration into the sludge is achieved by using the collective weight of the sampler and pipe sections. Once the desired depth is achieved, the nose cone is retracted into the cylinder, forming an annulus between the cone and cylinder. Gases and liquids pass through a vent at the top of the cylinder, allowing the sludge to be trapped in the cylinder. After the cylinder is closed, the sampler is raised out of the tank into a shielded cask (910).

7.8 The ability to collect closure samples of solid material remaining after single-shell tanks have been retrieved was needed. Several different methods have been deployed with the primary method being the off-riser sampling system (ORSS). The ORSS system consists of a remotely operated, mobile sampler and a sample jar carrier. This tool is designed to collect residual waste samples from any location on a tank floor. The ORSS is lowered through a 12-inch diameter riser to the tank bottom. The sampler is then maneuvered remotely to collect a waste sample. The sampler deposits the waste material into a sample jar located in the sample carrier, which is then raised into the glovebag at the top of the riser. The sample is replaced with an empty jar and the carrier is lowered back into the tank for collecting the next sample. Fig. 7 below shows the ORSS including the mobile sampler and carrier (11).

## 8. Other Sampling Techniques

8.1 Robotic arms have also been deployed in waste tanks to retrieve samples. Light-Duty Utility Arms (LDUAs) are mobile, multi-axis positioning systems that can access tank contents through the risers. The LDUAs provide a flexible robotic deployment platform for many applications, including sampling. Using the Extended Reach End-Effector (EREE), waste samples have been retrieved from Hanford tanks for laboratory analysis. The extended-reach arms allow samples to be taken throughout the tank, not

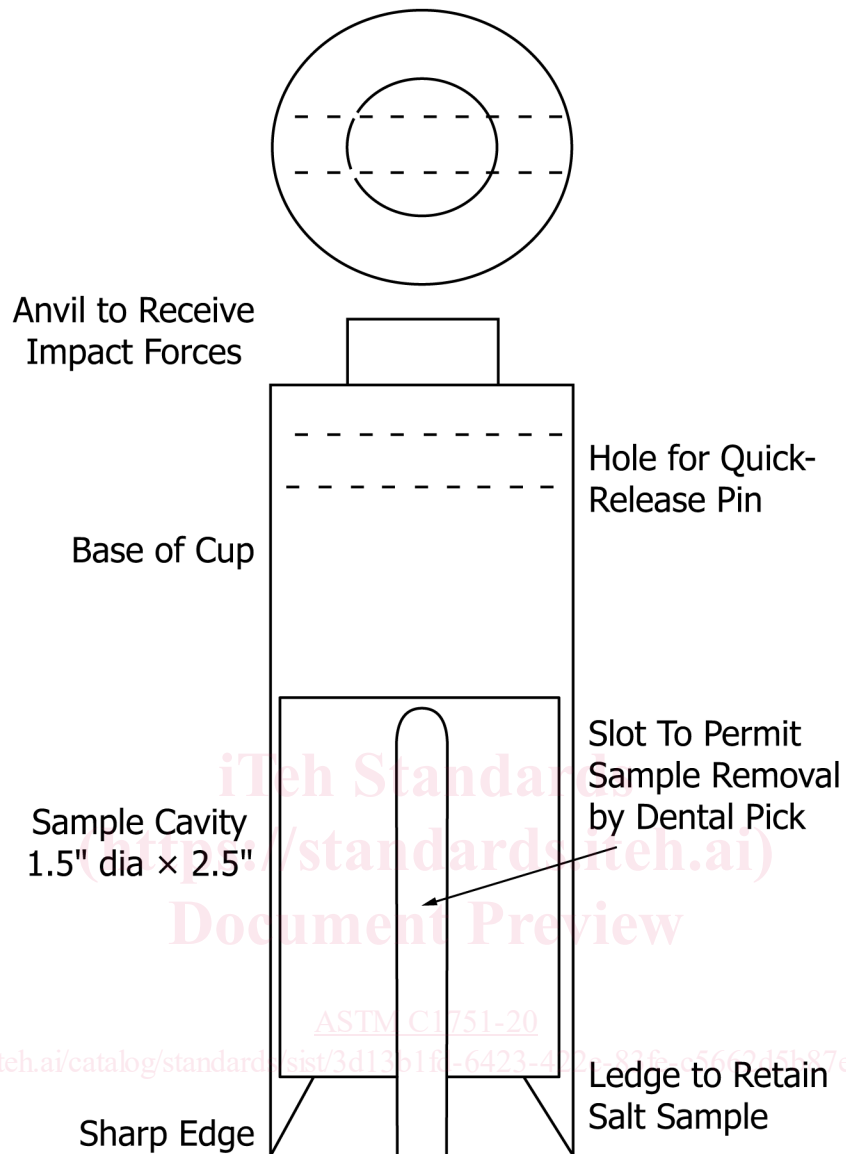


FIG. 23 Savannah River Site Salt-Cake Sample Cup

just directly under risers. Samplers are detachable from the arm and can be designed to obtain samples of different volumes. Current samplers have a clamping force of 50 to 300 lbs and can capture both liquids and solids (1012).

8.2 The clamshell sampler is a remotely operated end-effector tool designed for obtaining residual waste samples from locations within the tank. It consists of a battery-powered control unit with cable, a push pole adaptor, a motorized retrieval claw that has been modified to accept a sampling scoop. The sampling scoop may be used repeatedly to collect all samples in a tank, and may also be positioned over the waste to be sampled by maneuvering the cable with an extended-reach sluicer. This method may involve using the Foldtrack (a remote-controlled, track vehicle with a blade in front) to move solids from selected locations to a riser where they can be collected with the clamshell. The Foldtrack-clamshell method is preferred when a Foldtrack retrieval tool is already deployed in the tank (13).

8.3 The finger trap sampler is essentially a short stainless steel pipe that is open at one end. Thin, flexible, overlapping steel blades, designed to hold solids inside the sampler, are located just inside this end. Sampling is performed by dropping the sampler vertically, with the open end at the bottom, onto the waste. Solids are forced from the drop to pass the inwardly flexible steel blades into the sampler and are trapped by the blades. The lower section of the sampler where the sample material is collected is unscrewed from the top section, placed in a jar and shipped to a laboratory for analysis. Another clean lower section is attached to the sampler for the next sample (13).

8.4 The drag sampler consists of two units connected with a cable. The lower unit is a sample jar attached to a heavy stainless steel shroud, which acts as a funnel to collect solids as the sampler is dragged through the waste. The upper unit is primarily a