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Packaging and Transportation of Radioactive Liquid at the U.S. Department of Energy Hanford Site

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PACKAGING AND TRANSPORTATION OF RADIOACTIVE LIQUID AT THE U.S. DEPARTMENT OF ENERGY HANFORD SITE

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1. INTRODUCTION

Beginning in the 1940's, radioactive liquid waste has been generated at the U.S. Department of Energy (DOE) Hanford Site as a result of defense material production. The liquid waste is currently stored in 177 underground storage tanks (UST). More than 227 million L of liquids, sludges, and salt cakes are stored in these tanks. As part of the Hanford Site's new environmental cleanup mission, programs are underway to sample, characterize, perform process prototypes, stabilize, and remove the liquid from the tanks. Such actions are necessary because of the age of the USTs.

As part of the tank remediation efforts, Type B quantity packagings for the transport of large volumes of radioactive liquids are required. There are very few Type B liquid packagings in existence because of the rarity of large-volume radioactive liquid payloads in the commercial nuclear industry. It is only in recent years that the DOE has begun investigating the development and use of Type B liquid packagings as a part of its relatively new environmental cleanup mission.

Development of aboveground transport systems for large volumes of radioactive liquids involves institutional, economic, and technical issues. Although liquid shipments have taken place under DOE-approved controlled conditions within the boundaries of the Hanford Site for many years, offsite shipment requires compliance with DOE, U.S. Nuclear Regulatory Commission (NRC), and U.S. Department of Transportation (DOT) directives and regulations[1,2,3]. At the present time, no domestic DOE nor NRC-certified Type B packagings with the appropriate level of shielding are available for DOT-compliant transport of radioactive liquids in bulk volumes (i.e., greater than 1-L volumes). Other technical issues, such as hydrogen gas generation, must also be addressed.

This paper will provide technical details regarding current methods used to transport such liquids on and off the Hanford Site, and will provide a status of packaging development programs for future liquid shipments.

2. BACKGROUND

The Hanford Site has operated since 1943 with the primary purpose of plutonium production. The current mission of the 1,450-km^2 site is environmental cleanup. The Hanford Site is located in the arid southeast region of Washington State (northwest area of the United States).

Plutonium was produced by the irradiation of enriched uranium, followed by a series of chemical processes that separated the plutonium from the uranium and fission products. The chemical process liquid waste has been stored in 177 USTs for future retrieval, treatment, and final disposal. The USTs are up to 50 years in age, of several design types (i.e., single and double shell), and have volumes up to 3.8 million L. Over 227 million L of waste are stored in the tanks. The waste forms include various mixtures of sludge, liquid, salt cake, or slurry. The waste is alkaline, consisting primarily of sodium nitrate and nitrite salts and metal oxides. Principal radionuclides include uranium, uranium fission products, and fission decay products.

Final disposition of the tank waste is of a high priority for safety and environmental cleanup. Certain tanks are of concern because of flammable gas generation; high heat load; or potential volatile mixtures of nitrates, organics, and ferrocyanides. Other tanks have already leaked into the soil. Specific criteria are in place to identify those tanks that are of primary concern (i.e., "watch-list tanks").

Activities to predict tank waste characteristics to date have been necessarily conservative because of the potential for severe consequences from such large volumes of waste. Therefore, databases, which provide bulk average radionuclide and chemical inventories are typically conservative to encompass all uncertainties and to ensure that safety analyses based on the data are bounding.

Additional tank samples are needed for laboratory analysis to more accurately characterize the waste constituents, and to develop the process technologies needed for disposition of the waste. Sampling activities have been underway since the mid-1980's, typically using a core sampling mechanism through a tank riser. The samples are transferred to a hot cell facility, usually the 222-S or 325 Laboratories on the Hanford Site. There, the samples are analyzed. Because of the anticipated increase in future characterization activities, these laboratories will likely become overloaded. Therefore, packagings are needed for shipments to other laboratories off the Hanford Site, most likely located at either the Idaho National Engineering

Laboratory (INEL) or the Los Alamos National Laboratory (LANL).

In addition to sample characterization, packagings are also needed to support aboveground transfers of liquid from tanks in cases where the underground piping system is unable to support such transfers. These packagings may also be used for limited campaigns such as the shipment of process development quantities (i.e., 1,000 to 10,000 L) of tank liquids.

3. PAYLOAD DESCRIPTION

The tank waste consists of an approximately even distribution of four general physical forms: supernatant, sludge, slurry, and salt cake. Supernatant is the liquid portion of the waste, consisting primarily of nitrate and nitrite salts and soluble radionuclides such as ^{137}Cs. The sludge primarily contains the insoluble components of the waste, primarily metal oxides, hydroxides, and insoluble radionuclides such as ^{90}Sr. Sludge has a consistency ranging from a thick mud to a nearly dry-hard substance. Slurry is a mixture of supernatant and sludge, with a consistency of thick soup. Salt cake is the result of the evaporation of the supernatant. Therefore, salt cake has the same chemical composition of the supernatant, but has a hard crusty consistency.

The following is a brief summary of the physical characteristics of the tank waste:

Physical condition	Description/data
Temperature	Near ambient to 82 °C
Density	1.1 to 3.0 g/cm^3
Water percentage	Nearly dry to 50%
Heat load	0 to 0.2 W/L

Table 1 lists the estimated worst-case concentrations of each radionuclide. These concentrations are derived by taking the highest predicted concentration of each radionuclide from any one of all the Hanford Site tanks. Because not all radionuclides are at their maximum concentration in the same tank, an actual liquid sample will be less active than this source term.

4. ONSITE PACKAGINGS IN USE

There are several onsite packaging systems in place for the transfer of tank samples from the tanks to onsite laboratories at the Hanford Site, typically a distance of no more than 30 km. Transfers within Hanford Site boundaries follow a formal set of DOE directives that require DOT-approved packagings or packagings with an approved onsite safety analysis report.

The three most common packagings in use are the Onsite Transfer Cask (OTC), the Neutralized Current Acid Waste (NCAW) Cask, and Sample Pigs. The OTC and NCAW casks are used to ship samples enclosed in a core sample device that drills the sludge/solid sample from the salt cake layer, and is pulled through the tank riser into a shielded receiver. The OTC or NCAW casks are connected to the shielded receiver for downloading of the core sample. The Sample Pigs are used for smaller "grab" samples, which are manually removed from the tank by a variety of means.

The OTC consists of two concentric cylindrical containers: the cask and the liner. The cask is constructed of two concentric stainless steel shells encasing 2.5 cm of lead shielding. The cask lid is a modified blind flange. The stainless steel liner assembly, sealed with an expansion-type stopper, holds the payload (quadralatch/sampler assembly). The cask is 114 cm long, 13 cm in diameter, and weighs 181 kg. No overpack is used. The onsite Safety Analysis Report for Packaging (SARP) for the OTC approves up to 500 mL of fissile exempt liquids, solids, or slurries.

The NCAW Cask is similar in design and use to the OTC. It is generally used for higher dose samples. It is constructed of two concentric stainless steel shells encasing 14 cm of lead shielding. The overall dimensions of the cask are approximately 122 cm long by 36 cm in diameter. Inside the payload cavity, the cask retains a scoop assembly, which accommodates a sealed liner that contains the payload. The system allows the liner to be extended into a hot cell. The NCAW cask is transported within a DOT Specification 21PF overpack. Weight of the cask and its overpack is 2,950 kg. The onsite SARP for the NCAW cask approves up to 30-A_2s, or approximately 250 to 850 mL of fissile-exempt liquids, solids, or slurries.

The Sample Pig is constructed of a stainless steel shell with 4.8 cm of lead shielding. Additional lead liners may be added. The Sample Pig is 32 cm long by 15 cm in diameter, and is held within a stainless steel, leak-testable, Sample Pig Shipping Container (35 cm long by 20 cm in diameter). The Sample Pig Shipping Container is secured within a 208-L drum, which is further secured within an N-55 Overpack [identical to that certified under NRC Certificate of Compliance (CoC) USA/9070/B(U)]. The overpack is 122 cm tall by 81 cm in diameter. Overall weight of the entire packaging system is 261 kg. The packaging is approved by an onsite SARP for onsite transfers of up to 2,500-A_2s (nominally 100 mL) of fissile-exempt solids, liquids, and slurries.

5. FUTURE ONSITE PACKAGING-- LR-56 LIQUID WASTE CASK

Approximately 46 single-shell tanks at the Hanford Site contain interstitial and supernatant liquids that may leak from the tanks at any time, due to the age of the tanks. Typically, pumping via pipeline to other tanks is used whenever such leakage is detected. However, various conditions may preclude such transfers to take place, thus the need for a flexible auxiliary system. There are also needs to transfer bulk quantities of tank liquids for limited campaigns such as process development. Such a system must meet DOE-approved onsite packaging standards for Type B quantities of radioactive materials.

At the present time, no domestic DOE nor NRC Type B packagings with the appropriate level of shielding are available for transport of radioactive liquids in bulk volumes (i.e., greater than 1-L volumes). Because of the expense and time involved in designing, fabricating, and approving a new Type B packaging, it was decided that the best way to meet Tank Farm needs was to select an existing Type B packaging, the LR-56 Cask System (Figure 1), used by the French as a part of their nuclear program. This system is currently being purchased from NUMATEC Inc. (a Cogema Inc./SGN Company), with slight modifications for Hanford Site use (e.g., an integrated sluicing system for removal of particulates).

The LR-56 is licensed for Type B liquids by a French CoC F/309/B(U)F. In general, the Type B performance requirements of the French regulations are virtually equivalent to those of the United States, as they are ultimately based on the International Atomic Energy Agency (IAEA) Safety Series 6 requirements used by both countries[4]. The LR-56 is designed and certified to carry 4,000-L volumes of liquid effluents between French reprocessing plants. The design incorporates 50 mm of lead equivalent shielding. The exterior of the LR-56 cask (including thermal/impact shield) is 3.7 m long by 2.15 m in diameter. The currently approved maximum gross weight is 23,100 kg.

For use on the Hanford Site only, an approved onsite SARP would authorize the use of the LR-56 for transfer of radioactive liquids. The SARP is necessary because the French CoC for the LR-56 is not recognized for domestic use in the United States, unless an expensive and time-consuming licensing process is pursued through the DOE or NRC. Such a license is not necessary for onsite use. The onsite SARP will document the Type B performance of the LR-56, analyze its use for the single-shell tank liquid source term, and establish operational controls. Approval of the SARP, currently in process, will authorize the LR-56 for onsite use (anticipated for 1996).

6. FUTURE OFFSITE PACKAGINGS FOR TANK CHARACTERIZATION

To support characterization activities for the single- and double-shell tanks at the Hanford Site, the National Laboratory Program has a need to ship tank core samples to offsite laboratories in 250-mL to 4-L volumes. At the present time, no certified Type B packagings are available for transport of liquid radioactive samples in volumes of 250 mL and greater.

Because of the expense and time involved in designing and certifying a new Type B packaging (up to 4 million U.S. dollars and 5 years), it was decided that the best way to meet Tank Farm characterization schedules was to select an existing Type B packaging. A packaging search was performed, concluding that the PAS-1 Cask (Figure 2) was most amenable to an upgrade to enable shipments of larger volumes of liquids.

The PAS-1 Cask design was developed by VECTRA Technologies Inc., and is licensed for Type B liquids by the NRC CoC USA/9184/B(U). The cask was originally certified to carry small volumes (15 mL) of post-accident liquid samples from commercial reactors. These casks have never been used for such a purpose, but are on standby if an accident ever occurs. Their need was determined following the United States Three Mile Island incident.

For the purposes of shipping extruded tank core samples, the innermost "post-accident sample container" will be replaced with an array of shielded sample carriers, specifically designed for handling core samples from a hot cell facility. A revision to the PAS-1 CoC will be required to approve the different payload and increased sample volume. VECTRA Technologies Inc., under the direction of Westinghouse Hanford Company (WHC), performed the necessary analyses and amended the PAS-1 SARP to support the CoC revision.

Up to eight steel or lead-shielded hot cell sample carriers will fit in a rack inside the PAS-1 primary containment vessel. Each carrier has a volume of up to 500 mL. The primary containment vessel is nominally 56 cm tall by 51 cm in diameter. It is secured within a secondary containment vessel that includes 13 cm of lead shielding. Both the primary and secondary vessels incorporate leak-testable seals. The outermost level of packaging is a polyurethane foam overpack 168 cm tall by 122 cm in diameter. Gross weight for the PAS-1, with its shipping pallet, is approximately 6,350 kg.

Work is underway with the vendor of the PAS-1 (VECTRA Technologies Inc.) to obtain a revision to the cask's CoC, to allow shipment of up to 4 L of tank samples. Two PAS-1 Casks and several sets of shielded sample carriers have been purchased and are located at the Hanford Site. Shipments to offsite labs are anticipated in 1995, following DOE approval of the SARP amendment and issuance of a revised CoC.

To support the Type B PAS-1 Cask, smaller Type A packagings are also being developed. These packagings will be supplied by commercial vendors and by changing custody of existing packagings from completed DOE programs. Typical Type A packagings will range in volumes of 10 to 500 mL, and will include various levels of shielding from 0 to 2.5 cm (lead equivalent).

7. CONCLUSIONS

Packagings are in place and in use for onsite shipments of Tank Farm samples on the Hanford Site. The LR-56 Cask is being developed for the onsite transfer of bulk volumes of tank liquids, beginning in 1996. Offsite shipment needs will be met by the use of Type B PAS-1 Casks and a variety of Type A packagings. It is anticipated that significant offsite shipments of samples to offsite laboratories will begin early in 1995. Such shipments are an important link toward meeting characterization needs for the Hanford Site tanks.

8. ACKNOWLEDGEMENTS

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The author also acknowledges Gilles David and Gilles Clement of NUMATEC Inc. (a Cogema Inc./SGN Company) for their support of the LR-56 Liquid Waste Cask System, and Charles Temus of VECTRA Technologies Inc. for his support of the PAS-1 Cask.

9. REFERENCES

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[3]DOT, 1993, "Transportation," Title 49, *Code of Federal Regulations*, Part 173, U.S. Department of Transportation, Washington, D.C.

[4]IAEA, 1985, *Regulations for the Safe Transport of Radioactive Material*, 1985 Edition (as amended 1990), Safety Series No. 6, International Atomic Energy Agency, Vienna, Austria.

Table 1. Maximum Radionuclide Source Term.

Nuclide	Max conc. (Bq/cm^3)	Nuclide	Max conc. (Bq/cm^3)	Nuclide	Max conc. (Bq/cm^3)
^{225}Ac	3.85 E-05	^{93m}Nb	3.26 E+05	^{225}Ra	3.85 E-05
^{227}Ac	3.92 E-02	^{59}Ni	Negligible	^{226}Ra	6.62 E-07
^{241}Am	3.16 E+05	^{63}Ni	3.26 E+06	^{106}Ru	9.77 E+03
^{242}Am	6.73 E+02	^{237}Np	1.95 E+02	^{126}Sb	9.77 E+04
^{242m}Am	6.73 E+02	^{239}Np	3.00 E+02	^{126m}Sb	9.77 E+04
^{243}Am	3.32 E+02	^{231}Pa	8.81 E-02	^{79}Se	3.26 E+03
^{217}At	3.85 E-05	^{233}Pa	1.95 E+02	^{151}Sm	9.77 E+07
^{135m}Ba	Negligible	^{234m}Pa	3.01 E+03	^{126}Sn	9.77 E+04
^{137m}Ba	1.11 E+08	^{209}Pb	3.85 E-05	^{90}Sr	3.70 E+09
^{210}Bi	1.50 E-07	^{210}Pb	1.50 E-07	^{99}Tc	9.77 E+04
^{211}Bi	3.92 E-02	^{211}Pb	3.92 E-02	^{227}Th	3.92 E-02
^{213}Bi	5.11 E-05	^{214}Pb	6.62 E-07	^{229}Th	3.85 E-05
^{214}Bi	6.62 E-07	^{107}Pd	3.26 E+02	^{230}Th	1.63 E-04
^{14}C	1.47 E+05	^{210}Po	1.34 E-07	^{231}Th	1.50 E+02
^{242}Cm	3.42 E+02	^{213}Po	3.85 E-05	^{233}Th	Negligible
^{244}Cm	2.28 E+03	^{214}Po	8.25 E-07	^{234}Th	3.01 E+03
^{245}Cm	1.30 E-01	^{215}Po	3.92 E-02	^{207}Tl	3.92 E-02
^{60}Co	2.83 E+04	^{218}Po	6.62 E-07	^{233}U	2.64 E-02
^{135}Cs	4.88 E+02	^{238}Pu	3.26 E+04	^{234}U	3.01 E+03
^{137}Cs	1.11 E+08	^{239}Pu	4.88 E+05	^{235}U	1.50 E+02
^{221}Fr	3.85 E-05	^{240}Pu	1.30 E+05	^{238}U	3.01 E+03
^{223}Fr	5.88 E-04	^{241}Pu	1.63 E+06	^{90}Y	3.70 E+09
^{129}I	1.63 E+02	^{223}Ra	3.92 E-02	^{93}Zr	4.88 E+05

Figure 1. LR-56 Cask System.

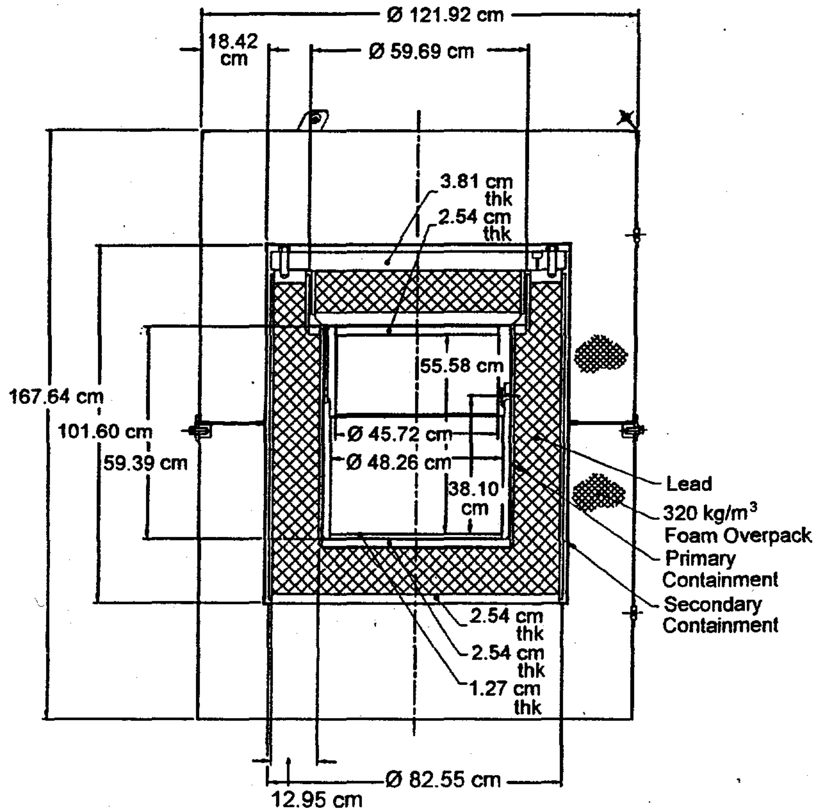
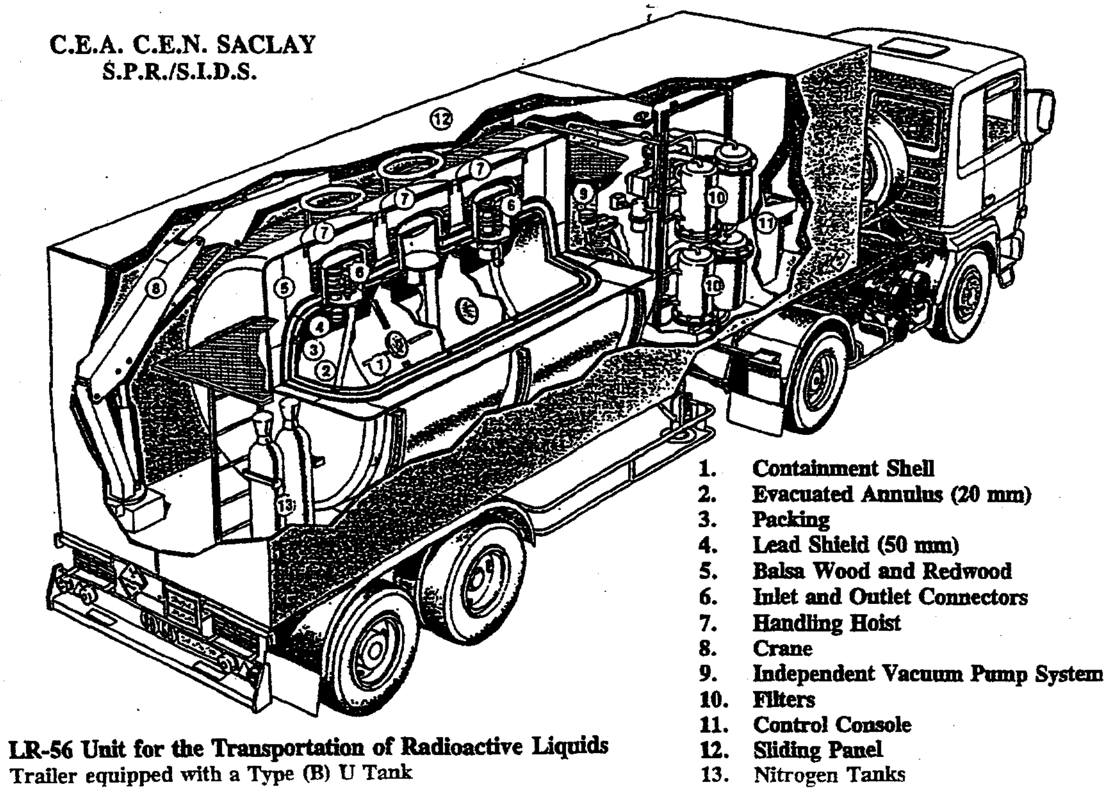


Figure 2. PAS-1 Detail Sketch.



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