Waste Containers for Extended Storage of Class A, B and C Wastes, Revision 1

Technical Report

Waste Containers for Extended Storage of Class A, B and C Wastes, Revision 1

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Final Report, August 2003

EPRI Project Manager
S. Bushart

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

ERS International, Inc.

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Principal Investigator
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REPORT SUMMARY

In response to the potential loss of LLW Disposal Capacity for Class B and C Wastes in 2008, EPRI is updating its guidance documents on the Interim Storage of LLW Wastes. This volume provides a comprehensive review of low-level waste (LLW) containers and container technologies to help utilities evaluate their options and make selections for extended on-site storage. This revision updates the listings of commercially available containers, adds international containers, and provides minor technical changes, as well as information related to waste forms for extended storage.

Background

Since the introduction of EPRI's Interim On-Site LLW Storage report series, at least three-quarters of the commercial nuclear facilities in the US lost access to disposal sites for varying periods ranging from eighteen months to several years. This resulted in interim storage of all LLW classes. Under current state legislation, the majority of plants will again lose access to disposal sites for Class B and C wastes beginning in mid-2008. Other situations will also arise from time to time, which will force plants to implement interim storage programs. It is clear, therefore, that there is a continuing need for guidance related to all aspects of interim storage, including waste containers.

Objectives

- To identify and evaluate available LLW containers and emerging technologies for their applicability to various waste types and to extended on-site low level radioactive waste storage;
- To identify available coatings and linings for extending the useful life of LLW containers during interim storage;
- To develop methodology to evaluate container coatings to select the containers best suited to specific waste types at specific sites.
- To identify any significant waste form information, approval authorities, and disposal site criteria that changed since issuance of EPRI report TR-105787, *Waste Forms for Extended Storage*.

Approach

With the help of industry experts, researchers gathered information from EPRI member utilities on commercially available containers, casks, and on-site storage modules currently in use at nuclear plants. They solicited detailed information on available containers and emerging technologies from container suppliers and manufacturers, as well as on container coatings and linings. They also conducted an extensive literature search on available containers, coatings, and regulatory issues.

Results

This report provides:

- A comprehensive discussion of available LLW containers and emerging container technologies. It discusses containers in terms of their applicability to specific waste types for both storage and subsequent disposal.
- An assessment of available container coatings and linings for LLW containers, focusing on their applicability to specific containers and waste types likely to be stored on-site.
- A methodology that each utility can use to evaluate containers and container-coating options in order to select those most likely to meet specific storage needs and requirements.
- Recent waste form information.

EPRI Perspective

Each utility faced with interim storage of LLW will evaluate its own situation relative to disposal. Those considering on-site storage will need to make informed decisions about licensing issues, facility design, storage duration and capacity, and waste form. EPRI anticipates periodic reviews and updates to the Interim On-Site Storage reports, which document existing industry experience and expert insight on LLW storage issues. Using these comprehensive data, utilities can make informed decisions based on the best available information

Keywords

Interim storage
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Waste containers
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Chris Baker, Exelon Nuclear
William T. Bullard, STP Nuclear Operating Company
James Cline, Cline & Associates
Lou De Ritis, Dufrane Nuclear Shielding
Tony Didgeon, VP Marketing w/ Duratek
John Etheridge, Entergy Services, Incorporated
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Paul H. Genoa, Nuclear Energy Institute
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Ken Hilton, ATG Nuclear Services
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1
INTRODUCTION

The Low Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) defined the timetable for states to provide for the disposal of low level radioactive waste (LLW). As of January, 1993, sited states were allowed to exclude access to waste generated outside of their region.

At the present time, there are only three regional LLW disposal facilities:

- <u>Hanford, WA</u> – Accepts Class A, B, C waste. Access limited to Northwest Compact and Rocky Mountain Compact.
- <u>Envirocare of Utah</u> – Accepts only Class A waste. Access open to all LLW generators.
- <u>Barnwell, SC</u> – Accepts Class A, B and C wastes. Access currently open to all LLW generators through June 2008. SC law limits access to Atlantic Compact after June 2008.

In summary a LLW disposal option for Class A waste will remain available for the foreseeable future. Disposal of Class B and C waste will remain available to a few plants in the northwestern US and those plants located in the Atlantic Compact for the foreseeable future. Current legislation will severely limit disposal of Class B and C waste after June 2008.

It must also be noted that some utilities have made an internal decision not to dispose of any waste at Envirocare of Utah, thereby limiting any potential associated environmental liabilities. After June 2008, these utilities will have no disposal option for any LLW.

In this situation, it is likely that interim on-site storage of LLW will be employed until another permanent disposal option is available. The term “interim storage” means processing and/or packaging waste for efficient and safe storage until a permanent disposal option is available. Safety, regulatory and technical issues make this seemingly simple task more complex. Moreover, the uncertainties surrounding the duration of storage, the projected volume of LLW to be generated, and the final waste acceptance criteria of any new disposal site; further complicate the process.

Consequently, safe and efficient interim storage will require a detailed examination of licensing requirements and regulatory implications. These must then be combined with each individual utility's available storage space, waste volume projections, estimated storage duration and estimated facility cost.

With these considerations in mind, how does each utility determine its own storage/disposal solution? EPRI has responded to this question by initiating the Interim On-Site Storage of Low Level Waste series of guidance reports. The purpose of this project is to identify a comprehensive set of technical and regulatory considerations that must be addressed by any utility in planning for the addition of an interim on- site storage capability. The intent of this project is to present this information in a format that is clear and useful, without being prescriptive in nature. This will allow utility personnel to use the information, as appropriate to their unique situation and needs.

1.1 Project Overview

The project is organized to focus on five (5) distinct aspects associated with extended on-site storage. Each of these topical areas is being published as an independent volume:

Volume 1: Licensing and Regulatory Issues
Volume 2: Facility Design Options
Volume 3: Waste Volume Projections and Data Management
Volume 4: Waste Containers for Extended Storage
Volume 5: Waste Forms for Extended Storage

Each volume contains the same overall format, including a Table of Contents, Introduction, Methodology, Report Text, Bibliography and/ or References, (including this report) and a Glossary.

1.2 Purpose of This Report

The purpose of this report is to provide a comprehensive review of LLW containers and container technologies. The objective is to assist utilities in selecting containers for on-site storage pending the availability of new disposal sites.

A principal goal in container selection is to minimize reprocessing and repackaging of the wastes at the end of the storage period. Other primary considerations are that the container should provide protection against:

1. internal corrosion or degradation from wastes, stabilization media, or waste breakdown products that would result in container breaching or rejection by the disposal site,

2. external corrosion during storage that would cause breaching or rejection by the disposal site,

3. puncture and rupture in routine handling during storage and retrieval;

4. radiation damage or biodegradation that would similarly cause breaching or rejection; and

5. rejection by the eventual disposal site due to container material, container construction, or unacceptable waste forms.

Each of the above items are discussed in detail in sections three through seven of this report, including controlling or mitigating factors. The following additional information is included to provide the user of this document with a comprehensive review of the issues affecting LLW container storage:

1. evaluation of the present and anticipated stabilization and transportation regulations and their consequences for container use;
2. current and anticipated container disposal practices and criteria,
3. availability of present containers and new container technologies; and
4. container storage practicalities (shielding, stacking, access, handling, space, etc.).

Data for the evaluations resulted from studies of present and proposed regulations, surveys of utilities and container suppliers, studies of container topical reports, other literature searches, (including foreign experience), and discussions with utilities, disposal sites, container suppliers, and state and federal regulatory and compact agencies.

This document is limited to considerations of routine operating wastes, such as dry active wastes, evaporator bottoms, filter sludge, resins, and filter cartridges. It considers neither activated hardware nor liquid wastes.

1.3 Waste Forms for Extended Storage

Information is also provided in this report related to waste forms for extended storage. As indicated above, EPRI has a separate report on *Waste Forms for Extended Storage*, TR-105787. The vast majority of the waste form information in that report remains valid; however some information, approval authorities, and disposal site criteria has changed. Because the changes are relatively few in number, a separate report is not justified, and updated waste form information is included herein as appropriate.

1.4 Use of the Acronym CRCPD

The Conference of Radiation Control Program Directors, Inc. (CRCPD) is a nonprofit professional organization whose primary membership is made up of radiation professionals in state and local government who regulate the use of radiation sources. Other members include individuals with an interest in radiation protection.

The mission of the CRCPD, as stated on their web site at www.crcpd.org, is "to promote consistency in addressing and resolving radiation protection issues, to encourage high standards of quality in radiation protection programs, and to provide leadership in radiation safety and education." The CRCPD accomplishes its mission in part by making recommendations for suggested regulations to participating States, and the States typically adopt those recommendations in new State regulations.

The CRCPD is referenced numerous times in this EPRI report. That is because the CRCPD E5 Committee has taken on the role of reviewing and making approval recommendations for disposed waste forms and LLW containers. There is a high probability that the recommendations of the E5 Committee will be incorporated into the regulations applicable to, and the operating licenses for, all LLW disposal facilities. This report and all future LLW interim storage reports which address waste forms or LLW containers will incorporate any applicable recommendations of the E5 Committee.

1.5 Time Value of the Technical Data

As with all technical information, the regulatory requirements, disposal site criteria, and state-of-the-art practices will change over time. Every effort has been made to ensure that all technical data, regulatory requirements, disposal site criteria, etc., are current through the end of 2002. It is likely that the most dynamic issues will be those involving new disposal site criteria. It is therefore incumbent upon the user of this report to remain current with advances in LLW technology, particularly with regard to on- site storage requirements and disposal site criteria for their specific regional compact.

1.6 Organization of the Report

Section 2 follows this Introduction and is entitled the Methodology for Selecting Waste Containers (referred to hereinafter simply as the Methodology). The Methodology is intended to guide the user through the thought processes necessary to evaluate and select containers appropriate to extended LLW storage. Other report sections are referenced to assist the reader in locating detailed information necessary to make the judgments requested by the Methodologies. Section 2 also contains summaries of container options for various waste types, container acceptance considerations, and container coatings and linings. It is not intended that the Methodology be directive in nature, as it is essential that each utility tailor its approach to on-site storage so as to best serve its own needs, objectives, and regional disposal criteria.

Section 3 addresses the Applicable Regulations and Guidance Documents. This section analyzes the primary NRC regulations and guidance documents related to on-site storage. It also discusses existing disposal site criteria--as they relate to LLW containers-- where such information is available.

Section 4 documents existing utility practices with regard to LLW containers. This section addresses dry active waste containers, wet waste containers, and stabilization processing.

Section 5 focuses on currently available LLW containers, and **Section 6** addresses new technologies for LLW containers, specifically as they might apply to extended storage. It includes detailed discussions on protective container coatings and linings.

Section 7 provides a comprehensive look at LLW container selection considerations. As such, it provides the primary connection between container selection and on-site storage facility operations.

Section 8 captures lessons learned for waste container selection, storage, and handling from commercial nuclear power plants during construction and operation of LLW interim storage facilities. Lessons learned are also provided for waste forms.

A listing of applicable References and a Glossary are provided following the main body of the report. The Appendix lists the standards to which protective coating testing is performed and is relevant to an understanding of the coating evaluation addressed in Section 6.

1.7 Recommended Approach to Using This Report

It will be a natural tendency for most users to want to jump right into the Methodology contained in Section 2 of this report. However, the reader is cautioned to guard against using the Methodology as a stand-alone document.

It is suggested that the reader first look over the entire report so as to be comfortable with the format. Next, read the Methodology in Section 2 to identify portions that apply to their utility's situation. Then, before pursuing any specific issue, read the related information in Sections 3 and 4 to ensure a thorough understanding of all aspects of the issue or requirement.

1.8 Clarification of the Term "Storage"

The term "storage" is used throughout this report to describe existing or planned on-site LLW facilities. It is important to note that all such facilities were not constructed for LLW 'storage." Instead, some of these facilities were designed as interim holding areas while preparing LLW for shipment. Others were constructed as LLW staging areas pending one of the following situations:

1. Awaiting the accumulation of a sufficient number of LLW packages to constitute a full shipment.

2. Awaiting laboratory analyses for packaged LLW. Such analyses are necessary for accuracy of waste classification and shipping document preparation.

3. Awaiting relief from temporarily suspended access to existing disposal sites.

4. Awaiting approval from a disposal site to initiate a shipment pursuant to the advance notification requirements of the particular State or compact authority.

5. Awaiting approval from the NRC, disposal site, or other agency or consignee to ship the waste in a specific container, waste form, or package.

6. Temporary secure holding area during periods of an elevated national security threat level.

These clarifications are significant to several utilities operating under specific licensing or other legal/contractual limitations related to on-site storage. Hence, for the purposes of this document, the term “storage” is intended to mean interim, extended storage and any situation involving the temporary holding or staging of LLW.

2 METHODOLOGY FOR SELECTING WASTE CONTAINERS

2.1 Overview

This Methodology was developed for evaluating waste containers and container options for on-site storage of low level radioactive waste (LLW). As an alternative to performing independent container research and evaluations, a utility may use this Methodology to identify containers available for their unique requirements and objectives. In particular, the Methodology provides selection guidance on containers which:

1. meet the NRC regulations in 10CFR Parts 61 and 71, the Branch Technical Positions, the various NRC Bulletins, Information Notices, Generic Letters, and similar NRC documents dealing with acceptable waste packaging for disposal;

2. address the various disposal site and anticipated future state compact criteria for waste acceptance;

3. meet other requirements of the DOT/NRC regulations in 49CFR and 10CFR71 for transportation of wastes; and

4. optimize container stability and integrity during extended interim storage.

Selection of containers by a utility for storage and disposal of radioactive waste involves a combination of factors unique to each particular site and radwaste processing practice. There are at least several containers available for every waste stream and packaging process, and their selection may be, in part, subjective.

Hence, <u>the selection methods in this section are intentionally non-prescriptive</u>. As such, they serve primarily to indicate the available choices and the considerations important to appropriate selection of containers.

Moreover, the Methodology in this section should be used in combination with the referenced material in Sections 3 through 7. Container choice is also affected by storage facility design and waste form considerations. These are explicitly addressed in Volumes 2 and 5 of the EPRI Interim On-Site Storage of LLW report series (References 1 and 2, respectively) and should be reviewed in conjunction with this report.

Another important consideration for container selection is a reduced risk of repackaging the waste prior to shipment. However, most unsited disposal compacts have not developed disposal criteria for containers. Thus, the bases for the Methodology are:

1. current and anticipated regulations and disposal criteria (Section 3);

2. commercially available containers (Section 5);

3. new container technology (Section 6); and

4. container acceptance (NRC, compacts, etc.) and technical considerations (Section 7).

This part of the report is divided into four subsections, in addition to this Overview. Subsection 2.2 is the actual Waste Container Selection Methodology. Subsections 2.3 through 2.5 are summaries of Container Storage Options, Storage Container Selection Considerations, and Container Coating Attributes and Applications, respectively. These last three subsections are included to support the Methodology and to provide easy access to summary data.

2.2 Waste Container Selection Methodology

Step 1. When do you anticipate a need for interim storage for each class of waste? (enter “now” or a future date)

Class A waste __________
Class B waste __________
Class C waste __________
GTCC waste __________

Step 2. What is your anticipated storage duration? _____years

(See ISP Volume 2 for methodology.)

Step 3. Which waste types do you intend to store (circle Yes or No):

Compactible DAW	Yes	No
Noncompactible DAW	Yes	No
Incinerator ash	Yes	No
Solidified ash	Yes	No
Solidified resins	Yes	No
Dewatered resins	Yes	No
Dewatered filter cartridges	Yes	No
Encapsulated filter cartridges	Yes	No
Solidified evaporator concentrates and sludges	Yes	No
Oil	Yes	No

You should develop listing of specific containers to be used for each “Yes” answer above. A worksheet is included in Step 9 which can be used to make your selections as you work through this Methodology.

Step 4. Review the table of containers applicable to the common waste types (Table 2-1). (These container applications are discussed in detail in Section 2.3.) Yes means a recommended application; "No" means not recommended.

Table 2-1
Summary Of Containers Applicable To Common Waste Types

WASTE TYPE	SD/O	SB	BO	SL	HIC
Compactible DAW	Yes	Yes	Yes	No	No
Noncompactible DAW	No	Yes	Yes	No	No
Incinerator ash	Yes	Yes	Yes	Yes	Yes
Solidified ash	Yes	No	Yes	Yes	No
Solidified resins	No	No	No	Yes	No
Dewatered resin	No	No	No	Yes	Yes
Dewatered filter cartridges	No	No	No	Yes	Yes
Encapsulated filter cartridges	No	No	No	Yes	No
Solidified evaporator concentrates and sludges	Yes	No	Yes	Yes	No
Oil	Yes	No	Yes	No	No

CONTAINER KEY:

SD/O - Steel drum or drum overpack
SB - Steel box
BO - Box overpack
SL - Steel liner
HIC - Any approved HIC

Step 5. Each utility is faced with a unique combination of processing, storage and disposal considerations. Therefore, it is not appropriate to simply use the preceding recommendations as the sole rationale for container section. As a minimum, consider the Summary of Container Storage Options in Section 2.3 of this report. Careful consideration should be given to the comments at the end of each container summary. Refer to the SUMMARY SECTION column in Table 2-2:

Table 2-2
Summary Of Reference Sections For Detailed Discussion Of Container Properties And Applicability

SELECTION CONSIDERATION	SUMMARY SECTION	ADDITIONAL INFORMATION SECTIONS
Steel Drum	2.3.1	5.1
Drum Overpack	2.3.2	5.1
Steel Box	2.3.3	5.1
Box Overpack	2.3.4	5.1
Steel Liner	2.3.5	5.2
Concrete-Lined Liner	2.3.6	5.3
Polyethylene HIC	2.3.7	5.3
Ferralium HIC	2.3.8	5.3
Poly-lined SS HIC	2.3.9	5.3
Thermal-plastic-setting (coated) steel HIC	2.3.9	5.3
Poly-impregnated Concrete (PIC) HIC	2.3.10	5.3

Step 6. After reviewing the Summary of Container Options in Section 2.3, proceed to Section 2.4 to review the Summary of Storage Container Selection Considerations. Refer to the SUMMARY SECTION column on Table 2-3:

Table 2-3
Summary Of Reference Sections For Details On Container Selection Considerations

SELECTION CONSIDERATION	SUMMARY SECTION	ADDITIONAL INFORMATION SECTIONS
Container Acceptance	2.4.1	7.1,7.4,7.6
- NRC Container Approval	2.4.1	3.1,6.1-6.2,7.1
- DOT Container Qualification	2.4.1	3.3,7.6
- Compact Acceptance	2.4.1	3.2,7.4
Container Seals	2.4.2	7.3.2
- Reliability	2.4.2	5.1-5.3,7.3
- Re-opening Ease	2.4.2	5.1-5.3,7.3
Container Vents	2.4.3	7.3.2
- Reliability	2.4.3	5.1-5.3,7.3
Container Handling and Storage	2.4.4	7.5
- Lifting Devices	2.4.4	5.2-5.3, 7.5
- Stackability	2.4.4	5.2-5.4,7.5
Container Shielding	2.4.5	5.4
Container Coatings and Linings	2.4.6	5.3,7.3.1
- Container Interior	2.4.6	6.3-6.4,7.3
- Container Exterior	2.4.6	6.3-6.4,7.3

Step 7. If your review of Sections 2.3 and 2.4 does not produce an acceptable waste container selection for each waste type you plan to store, proceed to the sections listed under the column ADDITIONAL INFORMATION SECTIONS in Tables 2.2 and 2.3.

Step 8. Based on the information presented in Section 3.6, many containers may require protective anti-corrosion or abrasion coatings. Proceed to Section 2.5 to review the Summary of Container Coatings and Linings. (Refer to the SUMMARY SECTION column in Table 2-3. Also refer to the ADDITIONAL INFORMATION SECTIONS as needed.) Record your selections on the worksheet in Step 9.

Step 9. Complete the worksheet on the following page for waste container selections and container coating selections.

Table 2-4
Worksheet For Container And Coating Selections

Waste & Processing Method	Class A Container	Interior Coating	Exterior Coating	Class B/C Container	Interior Coating	Exterior Coating
Compactible DAW						
Handpacked						
Compacted						
Noncompactible DAW						
Handpacked						
Incinerator Ash						
Compacted/Handpacked						
Solidified						
Spent Ion Exchange Resins						
Dewatered						
Solidified						
Cartridge Filters						
Compacted						
Absorbed						
Dewatered						
Encapsulated						
Evaporator Bottoms						
Absorbed						
Solidified						
Oil						
Absorbed						
Solidified						

2.3 Summary of Container Storage Options

This section summarizes the container storage options discussed in Sections 3 through 7 of this report. These options are presented because it is not possible to know or anticipate in advance each utility's specific situation with regard to processing capabilities, storage facility design, storage duration, disposal site criteria, or available funding. The NRC no longer approves containers, and DOT container qualification requirements, as well as Compact acceptability of waste forms and container criteria, change over time.

The types of containers addressed in this section are:

1. Steel drum
2. Drum overpack (steel)
3. Steel box
4. Box overpack (steel)
5. Steel liner
6. Concrete-lined liner
7. Polyethylene HIC
8. Ferralium HIC and poly-lined stainless steel HIC
9. Thermo-plastic-setting (coated) steel HIC
10. Poly-impregnated concrete (PIC) HIC

Each container is summarized below as an independent subsection and includes specific storage application recommendations, advantages, and disadvantages. Also included are important comments which should be considered carefully in purchasing or using any of these containers.

2.3.1 Steel Drum

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	Yes
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	Yes
Solidified Resins	-	No
Dewatered Resins	-	No
Dewatered Filter Cartridges	-	No
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	Yes
Oil	-	Yes

ADVANTAGES

1. Inexpensive.
2. General NRC and compact acceptance.
3. Can be IP-2 or DOT Type A qualified.
4. Effective corrosion inhibitive coatings available.
5. Different wall thicknesses available.
6. Easy handled, stacked, stored and shipped.

DISADVANTAGES

1. Small size will generate more packages.
2. Steel susceptible to corrosion.
3. Requires care to avoid puncture or scratching of protective anti-corrosion coatings.

OTHER COMMENTS

1. Evaluate protective anti-corrosion coatings on all metal surfaces and components.
2. Consider heavier gauge containers to extend storage life.
3. Consider placing absorbent disk in drum prior to loading the waste.

2.3.2 Drum Overpack (Steel)

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	Yes
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	No
Dewatered Filter Cartridges	-	No
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	Yes
Oil	-	Yes

ADVANTAGES

1. Inexpensive.
2. General NRC and compact acceptance.
3. Can be IP-2 or Type A qualified.
4. Effective corrosion inhibitive coatings available.
5. Different wall thicknesses available, which may extend storage life.
6. Easily handled, stacked, stored and shipped.
7. Could possibly be used to protect internal container during storage, particularly in adverse environments.

DISADVANTAGES

1. Small size will generate more packages.
2. Steel susceptible to corrosion.
3. Requires care to avoid puncture or scratching of protective anti-corrosion coatings.

OTHER COMMENTS

1. Evaluate protective anticorrosion coatings on all metal surfaces and components.
2. Consider heavier gauge containers to extend storage life

2.3.3 Steel Box

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	- Yes
Uncompacted DAW	- Yes
Incinerator Ash	- Yes
Solidified Ash	- No
Solidified Resins	- No
Dewatered Resins	- No
Dewatered Filter Cartridges	- No
Encapsulated Filter Cartridges	- No
Solidified Evaporator Concentrates and Sludges	- No
Oil	- No

ADVANTAGES

1. Relatively large, inexpensive container
2. General NRC and compact acceptance.
3. Can be IP-1, IP-2, or DOT Type A qualified.
4. Effective corrosion inhibitive coatings available.
5. Different wall thicknesses available, which may extend storage life.
6. Easily handled, stacked, stored and shipped.

DISADVANTAGES

1. Steel susceptible to corrosion.
2. Requires care to avoid puncture or scratching of protective anti-corrosion coatings.

OTHER COMMENTS

1. Evaluate protective anti-corrosion coatings on all metal surfaces and components.
2. Consider heavier gauge containers to extend storage life.
3. Consider placing an absorbent pad in box prior to loading the waste.

2.3.4 Box Overpack (Steel)

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	Yes
Uncompacted DAW	-	Yes
Incinerator Ash	-	Yes
Solidified Ash	-	Yes
Solidified Resins	-	No
Dewatered Resins	-	No
Dewatered Filter Cartridges	-	No
Encapsulated Filter Cartridges	-	No
Overpack for Solidified Evaporator Concentrates and Sludges in Steel Drums	-	Yes
Oil Solidified in Steel Drums	-	Yes
Oil	-	Yes

ADVANTAGES

1. Relatively large, inexpensive container.
2. General NRC and compact acceptance.
3. Can be IP-1, IP-2, or DOT Type A certified.
4. Effective corrosion inhibitive coatings available.
5. Different wall thicknesses available, which may extend storage life.
6. Easily handled, stacked, stored and shipped.
7. Could possibly be used in to protect internal container during storage, particularly in adverse environments.

DISADVANTAGE

1. Steel susceptible to corrosion.
2. Requires care to avoid puncture or scratching of protective anti-corrosion coatings.

OTHER COMMENTS

1. Evaluate protective anti-corrosion coatings on all metal surfaces and components.
2. Consider heavier gauge containers to extend storage life.

2.3.5 Steel Liner

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	Yes
Solidified Resins	-	Yes
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	Yes
Solidified Evaporator Concentrates and Sludges	-	Yes
Oil	-	No

ADVANTAGES

1. Relatively inexpensive.
2. General NRC and compact acceptance.
3. Can be IP-1, IP-2, or DOT Type A certified.
4. Effective corrosion inhibitive coatings available.
5. Easily handled and stackable container geometries.
6. Puncture susceptibility less than for organic container materials (e.g., polyethylene or fiberglass).

DISADVANTAGES

1. Steel more susceptible to corrosion than polyethylene or fiberglass composites.
2. Requires care to avoid puncture or scratching of protective anti-corrosion coating.
3. Not acceptable for disposal of dewatered Class B or C wastes.

OTHER COMMENTS

1. Use protective anti-corrosion coatings on all metal surfaces and components.
2. Do not use for dewatered wastes that are Class B or C.
3. Possible future requirement for container venting of some wastes. Thus, liners with replaceable lids could be a better storage option.
4. Consider using removable lids to allow for dewatering after storage.

2.3.6 Concrete Lined Liner

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	No
Oil	-	No

ADVANTAGES

1. General NRC and compact approval.
2. Good mechanical strength.
3. Does not require protective anti-corrosion coatings.
4. Low susceptibility to chemical corrosion.
5. Easily handled and stackable container geometries.

DISADVANTAGES

1. Relatively expensive container cost.

2.3.7 Polyethylene HIC

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	No
Oil	-	No

ADVANTAGES

1. Accepted at Barnwell and Hanford commercial LLW disposal facilities for Class B and C stability when placed in a concrete overpack. Envirocare license accepts for Class A stability when placed in a concrete overpack.

2. Can be IP-2 or Type A qualified.

3. Less susceptible to corrosion than steel liners.

4. Does not require protective anti-corrosion coatings.

DISADVANTAGES

1. Slightly more expensive than steel liners.

2. Rounded container tops require pads for stacking.

3. Compacts may still require concrete overpacks.

4. High susceptibility to environmental conditions (e.g., sunlight).

5. More susceptible to damage during handling than NRC-approved HICs.

6. Strict controls required on chemicals placed in container.

OTHER COMMENTS

1. May not be acceptable to some compacts for stabilization of Class B and C wastes.

2. Consider using removable lids to allow for dewatering after storage.

2.3.8 Ferralium HIC and Poly-Lined Stainless Steel HIC

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	No
Oil	-	No

ADVANTAGES

1. Approved by NRC and existing compact disposal sites for Class B and C wastes. High probability of acceptance by many new compacts.
2. IP-2 or DOT Type A qualified.
3. Excellent resistance to environmental conditions.
4. Less susceptible to chemical corrosion than organic HICs or steel liners.
5. Does not require protective anti-corrosion coatings.
6. Easily handled and stackable container geometries.
7. Puncture susceptibility much less than for organic materials.

DISADVANTAGES

1. Expensive container cost.
2. Composite poly/stainless steel HICs are not stackable.
3. Composite HICs do not have easily removable lids for re-dewatering after storage.

OTHER COMMENTS

None

2.3.9 Thermo-Plastic Setting (Coated) Steel HIC

SUGGESTED STORAGE APPLICATIONS

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	No
Oil	-	No

ADVANTAGES

1. Can use relatively inexpensive steel liners.

2. Good corrosion control with mechanical strength.

3. Easily handled and stackable container geometries.

4. Puncture susceptibility less than for organic materials.

DISADVANTAGES

1. Not yet approved. Must be submitted to the CRCPD E-5 Committee in lieu of each state since NRC terminated topical reports for LLW.

2. Requires care to avoid punctures and scratches of protective anti-corrosion coatings.

OTHER COMMENTS

1. HICs may not be acceptable to some compacts as the sole stabilization method for Class B and C wastes.

2.3.10 Poly-Impregnated Concrete (PIC-HIC)

SUGGESTED STORAGE APPLICATION.

Compacted DAW	-	No
Uncompacted DAW	-	No
Incinerator Ash	-	Yes
Solidified Ash	-	No
Solidified Resins	-	No
Dewatered Resins	-	Yes
Dewatered Filter Cartridges	-	Yes
Encapsulated Filter Cartridges	-	No
Solidified Evaporator Concentrates and Sludges	-	No
Oil	-	No

ADVANTAGES

1. Approved by NRC and existing compacts for Class B and C wastes. High probability of acceptance by many new compacts.
2. IP-2 or DOT Type A qualified.
3. Good mechanical strength; puncture resistant.
4. Does not require protective anti-corrosion coatings.
5. Low susceptibility to chemical corrosion.
6. Excellent resistance to environmental conditions.
7. Easily handled and stackable container geometries.

DISADVANTAGES

1. Relatively expensive container cost. Small size will result in many containers.
2. No current U.S. manufacturer/supplier, must obtain from Japan. (High transport cost to U.S. usually included in purchase price. Large minimum orders required.)

OTHER COMMENTS

None.

2.4 Summary of Storage Container Selection Considerations

This section summarizes the container selection considerations discussed in Sections 3 through 7 of this report. Selection considerations are grouped into the following six categories:

1. Container acceptance
2. Container seals
3. Container vents
4. Container handling and storage
5. Container shielding
6. Container coatings and linings

Each category is summarized below as an independent subsection and includes information on the applicable waste forms. Also included are references to other sections of the report where additional information may be obtained.

2.4.1 Container Acceptance

NRC Container Approval

Steel drums, boxes and overpacks are acceptable to the NRC as disposal containers for compacted, uncompacted and incinerated DAW which is Class A. They are not acceptable for Class B and C wastes unless the wastes are stabilized. Steel drums are also acceptable for unstable solidified evaporator concentrates and sludges.

Steel liners are acceptable to the NRC as disposal containers for all solidified Class A and stabilized Class B and C waste forms, including encapsulated filters. They are also acceptable for dewatered Class A resins and filters, but they are <u>not</u> acceptable for dewatered Class B or C waste forms.

Some metal and cement HICs are "NRC-approved" to provide waste stability for Class B or C wastes. Polyethylene HICs are <u>not</u> approved due to their structural deficiencies, and no request for approval of concrete overpacks for poly HICs was ever submitted to the NRC. Since the NRC has ceased issuing topical reports for LLW, no further NRC approvals will be possible.

Sections 2.3.6-2.3.11, 3.1, 6.1-6.2, 7.1

DOT Container Qualified

All DAW containers must be strong-tight, satisfy IP-2 criteria, or must be shipped in a cask.

Steel liners or HICs with Class A waste must either use an approved shipping cask or satisfy IP-2 criteria.

Steel liners or HICs with Class B or C waste not qualifying as LSA require Type B shipping casks.

Sections 3.3, 7.2

Compact Acceptance

Compacts will probably follow NRC guidance and current disposal site experience on container acceptance. This is specifically true for DAW and solidified waste forms.

Dewatered resins and filter cartridges in steel liners will likely be accepted by most compacts if Class A. Dewatered Class B and C wastes have been accepted by all sited compacts if placed in an NRC approved HIC. Polyethylene HICs may be disposed in concrete overpacks, but this is disposal site dependent. The CRCPD E-5 Committee is the current body that issues national waste form approval. It serves as an association of the individual states rather than for the Federal government.

Sections 2.3.6-2.3.11, 3.2, 7.3

2.4.2 Container Seal

Reliability

For all containers, the closure gaskets, bolts, clips, and welds should be compatible with the container life (which must be greater than the storage duration) and protected against corrosion.

Sections 5.1-5.3, 7.4

Re-opening Ease (for Waste Transfer or Repackaging)

DAW drums, boxes and overpacks are generally easy to re-open. However, opening a container with a compacted springback device may cause dispersal of the contents and radioactivity. Opening a container of incinerator ash may also result in the spread of contamination. Consideration should be given to using lever-lock drum rings for storage of drums or steel liners.

Some steel liners use spring clips which must be drilled out for re-opening. A few HICs have bolted lids for easy removal; most are very difficult to re-open. Similarly, some types of stainless-steel containers are not easily opened, particularly if the lids are welded in place.

Sections 5.1-5.3, 7.4

2.4.3 Container Vent

Reliability

Container venting is not required for DAW containers or for solidified wastes. However, container venting is required for HICs; future requirement for liners is probable. Thus, liners with replaceable lids could be a better storage option. Container gas vents (absolute-filter micropore plug) could plug through temperature--cycle “breathing” in dusty environments (internal or external).

Sections 2.3.5, 5.1-5.3, 7.4

2.4.4 Container Storage and Handling

Lifting Devices

For all stored waste forms, container lifting eyes, slings and grappling rings should be able to survive the storage period and should be protected against corrosion. Some engineered disposal facilities may require their integrity for the life of the container.

Stackability

For all waste forms, most of the loaded containers can safely be stacked two high. Steel boxes and drums can be stacked four high. Higher stacking requires specific engineering analyses. Polyethylene HICs may require a “stackable, grappable” support structure for stacking two-high. Note that composite poly/stainless steel HICs cannot be stacked.

Sections 5.2-5.3, 7.4.2

2.4.5 Container Shielding

For all waste forms, high-activity containers will require appropriate radiation shielding during storage and transport. Shipping cask weight and capacity limitations will influence the selection of container sizes.

Sections 5.4, 7.4.3

2.4.6 Container Coatings and Linings

Container Interior

The selected container construction material should be appropriate to the expected waste components and breakdown products (Reference 2). All coating applications should assure adherence in a complete layer over the entire surface, including seams and crevices.

For incinerated ash and DAW containers, interior coatings or linings should protect against internal atmospheric corrosion, mild chemical corrosion, and abrasion.

For solidified and encapsulated wastes, interior coatings or linings should have tough films to provide protection from mild corrosivity and from abrasion during the solidification process. Solidified evaporator concentrates and sludges may exhibit higher corrosion tendencies caused by entrained acids, alkalis, and organics.

Containers used for dewatered resins and filters should have a tough coating and superior resistance to corrosion caused by entrained acids, alkalis, and organics.

Sections 6.3-6.4, 7.4

Container Exterior

For all stored waste forms and containers, exterior container coatings should be selected on the basis of the environment of the storage area to inhibit corrosion. Selection should also be based on handling and storage conditions to provide reasonable protection against abrasion and puncture.

Construction material should be appropriate to the storage area environment.

The coating application should assure adherence in a complete layer over the entire surface, including seams and crevices.

Sections 6.3-6.4, 7.4

Note: A utility desiring to specify a particular coating for a container should request the certification data or test results from the manufacturer or coating vendor.

2.5 Summary of Container Coating Attributes and Applications

This section summarizes the container Coatings and their suggested applications.

Reference: Section 6.3

Table 2-5
Summary Of Coating Attributes And Applications

COATING MATERIAL	PRINCIPAL ATTRIBUTE	COATING APPLICATION EXTERNAL	INTERNAL DAW	INTERNAL Dewater	INTERNAL Solidif
AUTO-OXIDATION CROSS-LINKED RESINS					
Long-oil alkyd	HH, C	R	AC	NR	NR
Medium –oil alkyd	HH, C	R	AC	NR	NR
Short-oil alkyd	HH, C	R	AC	NR	NR
		R	AC	NR	NR
Melamine-modified alkyd	HH, C, O	R	AC	NR	NR
Silicone-modified alkyd	HH, C	R	AC	NR	NR
THERMOPLASTIC RESINS					
Vinyl	HH, C, A-A, O, PR	AC	AC	AC	R
Chlorinated rubber	HH, C, A-A	NR	AC	NR	R
Acrylic	HH, C	NR	AC	NR	AC
Solvent cutback coal tar	HH, C, A-A, PR	NR	R	NR	NR
Hot-melt coal tar	HH, C, A-A, PR	NR	R	NR	NR
THERMOSETTING RESINS					
Amine cure epoxy	HH, C, A-A, O, AB, PR	R	R	R	R
Amine adduct epoxy	HH, C, A-A, O, AB, PR	R	R	R	R
Polyamine cure epoxy	HH, C, A-A, O, AB, PR	R	R	R	R
Coal tar epoxy	HH, C, A-A, O, AB, PR	R	R	R	R
Urethane	HH, C, A-A, O, AB, PR	R	R	R	R

Key for Table 2-5:

WASTE FORM (for Internal Coating):

DAW	-	Dry active waste
Dewater	-	Dewatered resin or filter cartridge
Solidif	-	Solidified resin or encapsulated cartridges

CHARACTERISTIC:

HH	-	High humidity application
C	-	Condensation resistant
A-A	-	Acid and alkali resistant
O	-	Organic solvent resistant
AB	-	Abrasion resistant

APPLICATION RECOMMENDATION:

R	-	Recommended for the application
AC	-	Acceptable for the application
NR	-	Not recommended for the application
PR	-	Puncture resistant

3
REGULATIONS RELATED TO CONTAINER SELECTION

The NRC places requirements on the form of the waste and the permitted containers for storage and disposal. The U.S. Department of Transportation also places requirements on packages and packaging used in transporting the waste to the disposal site. Ideally, containers used for on-site storage and eventual disposal will meet all anticipated regulatory and disposal requirements.

This section summarizes the regulations that are relevant to waste containers for on-site storage. Many of these requirements have been in effect for years and are familiar to utilities and container suppliers.

Note: Throughout this section, rules in italics are direct quotes from the referenced documents.

3.1 NRC Regulations for Container Design and Testing

The NRC regulation 10CFR61.56 (Reference 3) provides the basis for regulating waste form and packaging wastes for disposal. It provides the minimum requirements for shallow land disposal of LLW to facilitate handling at the disposal site and to provide protection of public health and safety through intrusion and groundwater transport scenarios. NRC Branch Technical Position statements (Reference 4) further expand the NRC's position on waste form and packaging. Specifically, the NRC requirements for all waste form and containment are as follows:

10CFR61.56

1. *Waste must not be packaged for disposal in cardboard or fiberboard boxes.* This applies primarily to utility dry active waste (DAW).

2. *Liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of the fluid.* This rule applies primarily to utility oils.

3. *Solid waste containing liquid shall contain as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume.* Applicable to resins, evaporator bottoms, sludges, and filters.

4. *Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.* Applicable to decomposition of organic resins into hydrogen and methane.

5. *Waste must not contain, or be capable of generating toxic gases, vapors, or fumes harmful to persons "transporting, handling, or disposing of the waste. This does not apply to radioactive*

gaseous waste. This also applies to concerns over decomposition of organic resins into hydrogen and methane.

6. *Waste must not be pyrophoric. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable.* Not particularly applicable to most utility wastes.

7. *Waste in a gaseous form must be packaged at a pressure that does not exceed 1.5 atmospheres at 20°C. Total activity must not exceed 100 curies per container.* Not particularly applicable to utility wastes.

8. *Waste containing hazardous, biological pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the non-radiological materials.* Not particularly applicable to utility generated wastes.

The regulations in 10CFR61 have additional requirements for Class B and C wastes. These wastes must be able to maintain structural stability to inhibit slumping, collapse, or other failure of the disposal trench that could lead to radionuclide migration. Regulations stipulate a period of 300 years as the minimum time a Class B or C waste must retain its integrity. The additional requirements for these higher-level wastes are:

Branch Technical Position (BTP)

1. *The waste should be a solid form or in a container or structure that provides stability after disposal*

2. *The waste shall not contain free standing and corrosive liquids. That is, the wastes should contain only trace amounts of drainable liquid, and in no case may the volume of free liquid exceed 1% of the waste volume when wastes are disposed of in containers designed to provide stability, or 0.5% of the waste volume for solidified waste.*

3. *The waste or container should be resistant to degradation caused by radiation effects.*

4. *The waste or container should be resistant to biodegradation.*

5. *The waste or container should remain stable under the compressive loads inherent in the disposal environment.*

6. *The waste or container should remain stable if exposed to moisture or water after disposal*

7. *The as-generated waste should be compatible with the solidification media or container.*

The regulations also call for testing to grant approval (certification) of the waste forms. The NRC stopped issuing topical reports on LLW and no longer approves waste forms. Waste form submittals must now be made to individual states or to the E-5 Committee of the CRCPD as coordinated by the DOE at Idaho National Labs. Approved containers are called high integrity containers (HIC). The BTP for HIC acceptability states:

1. *The maximum allowable free liquid in a HIC shall be less than 1% of the waste volume.*

2. *HICs should have as a design goal a minimum lifetime of 300 years.*

3. *The HIC design should consider the corrosive and chemical effect of both the waste contents and the disposal trench environment. ... the thermal loads from processing, storage, transportation and burial ... and should consider the biodegradation properties of the proposed materials.* In particular, the container design should be tested with sulfuric acid and sodium hydroxide over a pH range from 4 to 11. It should also be tested with waste byproducts of EDTA, boric acid, carbon tetrachloride, citric acid and toluene and trench products of cyclohexanol, paraldehyde, trichlorethane, ethyl hexiadipate, tetrahydrofurin, O-cresol, benzoic acid, and methyl isobutyl ketone.

4. *The HIC should be designed to have sufficient mechanical strength to withstand horizontal and vertical loads on the container equivalent to the depth of proposed burial assuming a cover material density of 120 lbs/ft^3. The HIC should also be designed to withstand the routine loads and effects from the waste contents, waste preparation, transportation, handling and disposal site operations, such as trench compaction procedures.*

5. *For polymeric material, design mechanical strengths should be conservatively extrapolated from creep test data.*

6. *The HIC design should consider the radiation stability of the proposed container materials as well as the radiation degradation effects of the wastes… Polymeric HIC designs should also consider the effects of ultraviolet radiation.*

7. *The HIC should be capable of meeting the requirements for a Type A package as specified in 49CFR173.398(b) (Reference 5). The free drop test may be performed in accordance with 10CFR71.71 (Reference 6).*

8. *The HIC and the associated lifting devices should be designed to with stand the forces applied during lifting operations. As a minimum the container should be designed to withstand a 3g vertical lifting load.*

9. *The HIC should be designed to avoid the collection or retention of water on its top surfaces in order to minimize accumulation of trench liquids which could result in corrosion or degrading chemical effects.*

10. *HIC closures should be designed to provide a positive seal for the design lifetime of the container.*

11. *Prototype testing should be performed on HIC designs to demonstrate the container's ability to withstand the proposed conditions of waste preparation, handling, transportation and disposal.*

12. *HICs should be fabricated, tested, inspected, prepared for use, filled, stored, handled, transported and disposed of in accordance with a quality assurance program.*

The NRC stopped issuing topical reports on LLW and no longer approves waste forms. Waste form submittals must now be made to the E-5 Committee of the CRCPD or individual states.

The NRC also issued a set of Generic Letters, Information Notices, and Standard Review Plan sections that deal specifically with requirements for on-site storage of waste. These are discussed in detail in Volume I of the EPRI Interim On-Site Storage LLW report series (Reference 7). NRC Generic Letter 81-38 (Safety Guidance) provides the following guidance related to on-site storage of LLW containers (paraphrased):

1. *Container material must be compatible with the waste forms and with environmental conditions external to the containers to prevent significant container corrosion.*

2. *Unless storage containers are equipped with special vent designs which allow depressurization and do not permit the migration of radioactive materials, resins highly loaded with radioactive materials, such as BWR reactor water clean-up system resins, should not be stored for longer than approximately one year.*

3. *Container design should be evaluated with respect to container breach and the creation of flammable or explosive conditions.*

4. *Container design should account for the possibility of container breach and flammable or explosive conditions caused by radiolysis, biodegradation, or chemical reaction.*

5. *Container materials should not support combustion.*

6. *Containers must be selected based on data which demonstrate minimal corrosion from the anticipated internal and external environment for a period well in excess of the storage duration.*

7. *After storage, container integrity must be sufficient to allow handling during transportation and disposal without container breach.*

8. *Container materials or liners must be selected to insure against container breach.*

Generic Letter 81-38 (Reference 8)

1. *For storage purposes, solidified LLW shall meet disposal site solidified waste criteria. For purposes of this document, resins or filter sludges dewatered to the above criteria will be defined under this waste classification criteria.*

2. *If liquids exist which are corrosive, proven provisions should be made to protect the container (especially, liners or coatings) and/or neutralize the excess liquids. If deemed appropriate and necessary highly non-corrosive materials (i.e., stainless steel) should be used. Potential corrosion between the solid waste form and the container should also be considered, In the case of dewatered resins, highly corrosive acids and bases can be generated which will significantly reduce the longevity of the container. The Process Control Program (PCP) should implement steps to assure this does not occur; provisions on container material selection and precoating should be made to ensure that container breach does not occur during temporary storage periods.*

These rules clearly indicate the NRC's desire to assure the maintenance of container integrity during interim storage.

3.2 State Regulations Related to Container Use

The state licenses issued for the existing disposal sites contain additional requirements for waste disposal. The following sections describe specific disposal site criteria related to container use

3.2.1 South Carolina

Barnwell is the licensed LLW disposal facility for the Atlantic Compact. The practices and experiences at Barnwell will surely influence regulations at other sites. For waste disposal at the Barnwell site, South Carolina imposes the following additional requirements on HIC designs (Reference 9):

1. *The HIC shall be designed to have sufficient mechanical strength to withstand burial cover of 25 feet of soil.*

2. *The structural design of the HIC should be based on an empty container. No credit can be allowed for structural integrity of the waste.*

3. *The HIC is required to have a passive venting system. The venting system should be designed to withstand shipping, handling and disposal*

4. *The HIC shall be tested by dropping a fully loaded container on its bottom, side, bottom corner, top, and top corner from a height of 20 to 25 feet onto compacted sand or its equivalent. The container must retain all its contents.*

5. The SC Department of Health and Environmental Control (DHEC) has approved various forms of concrete and cement binders for waste disposed at Barnwell, as well as asphalt and the Dow media (Vinyl-Ester-Styrene). DHEC has also approved cement encapsulation for filters, VERI encapsulation of filters, and advanced polymer solidified resin for Class B and C waste. However, all containers must be placed in cement overpacks.

3.2.2 Washington

For waste disposal at the Hanford site, which is the Northwest Compact site, only approved solidification, stabilization, sorbent media, and HICs are accepted (Reference 10). The approved items correspond almost directly to the NRC approved items. This list contains various forms of concrete and cement, as well as asphalt and the Dow media (Vinyl-Ester-Styrene). Additionally, since the trench depths at Hanford are 45 feet, the Class B and C wastes or containers must withstand the load of the overburden. The remaining rules and requirements for disposal are generally consistent with those for the Barnwell site.

3.2.3 Utah

Envirocare of Utah is located in Clive, Utah. It's radioactive materials license applies only to Class A waste. In addition, Envirocare began accepting high dose rate Class A waste as "containerized waste" in 2001. This enables the disposal facility to receive all Class A waste both in the bulk form (containers with contact dose rates less than 200 mR/hr) and containerized waste (containers with contact dose rates greater than 200 mR/hr). These wastes are segregated into two different waste management facilities on the same site, which are referred to as the Bulk Waste Facility (BWF) and the "Containerized Waste Facility" (CWF) (Reference 53).

The Envirocare license specifies that all containerized waste shall be contained in metal, fiberglass, or plastic/poly containers, or it must be in an approved HIC. It should be noted, however, that the Envirocare license does not list any approved HICs, since only the Class A trench was opened, and stablized waste forms are not required in that trench. As of the beginning of 2003, the Envirocare license specifically states that, "There are no approved High Integrity Containers or steel-reinforced overpacks [approved] at this time." This does not mean that Envirocare will not accept HICs; they simply are not recognized at this time, since Class B and C wastes are not accepted. No Class A wastes disposed at Envirocare require 10CFR61 stabilization.

The following additional requirements and restrictions are imposed on wet solid wastes:

1. *Resins can only be disposed in HICs or liners. However, since there are not approved HICs, all HICs are processed and handled as liners.*

2. *Cartridge filters which are <u>encapsulated and characterized by concentration averaging</u> are not acceptable for disposal in the Class A trench. Utah wants to ensure that filters that were Class B or C prior to processing are not disposed in the Class A trench. (A proposed Envirocare license amendment for a Class B and C trench would allow concentration averaging and averaging the activity over a stable binder. However, a Class B and C license amendment is not approved—and not being actively pursued—as of the publication date of this report.)*

3. *As with the other two disposal facilities, only <u>approved</u> sorbent media and solidification agents can be used.*

To ensure that all waste complies with the CWF waste acceptance criteria, Envirocare has implemented a Generator Certification Program that eliminates a requirement to sample incoming shipments to the CWF. This Generator Certification applies to "Each waste type (e.g., Dry Active Waste (DAW), resins, solidified waste) identified by a Certified Generator as being generated and managed in accordance with the processes, procedures, and quality assurance controls specified in the generator certification review."

Accordingly, although Envirocare does not accept Class B or Class C waste, disposition of Class A containerized waste is allowed and will require submittal of plant procedures revised to include instructions on shipping to Utah.

3.3 DOT and NRC Regulations on Container Design and Testing

DOT and NRC regulations for the transportation of LLW categorize waste according to its activity levels and prescribe criteria for packaging that depend upon the waste category. The DOT regulations specify waste classifications as LSA-I, LSA-II, or LSA-III using an A_1, factor for each nuclide and a sum-of-the-fractions rule similar to that in 10CFR61. Wastes having all nuclide concentrations at the upper limits for NRC Class B and C wastes would exceed the limits for DOT-defined LSA material. However, most nuclide contents in utility LLW, except for irradiated hardware, are within DOT LSA-II limits.

Additional factors, A_2, determine requirements for DOT Type A or Type B containers, again using a sum-of-the-fractions rule. Typical low activity utility wastes, exclusive of irradiated hardware, require IP-1 or IP-2/Type A packages. (Any container with a dose rate in excess of 1 R/hr at 3 meters will require shipment in a Type B package.) Regulations also prescribe testing requirements for certification of the shipping containers. Waste storage containers, if they are to be later shipped for disposal, should comply with the DOT regulations.

The following additional transport requirements impact container selection for extended storage:

1. A_1 and A_2 values specify the maximum quantities of a nuclide permitted in Type A packages

2. There are three categories defined for LSA material: LSA-I (limited to contaminated soil), LSA-II (liquids, gases and solids), and LSA-III (solidified material or irradiated metal). Each category is limited by an A_2 ratio. The new definitions replace the old that relied on specific activity in millicuries per gram, correlated to the A_1, value of the material.

3. The total activity in any LSA package cannot exceed twice the A_1, values for the nuclides in the package using the sum-of-the-fractions rule. This is consistent with the IAEA criteria that the curie content of an unshielded LSA package shall not produce a radiation dose greater than 1 Rem/hr at a distance of 3 meters.

4. The DOT regulations define two categories of surface-contaminated objects, SCO-I and SCO-II, with different allowable fixed, removable, and total contamination levels for each category.

5. The regulations define and specify the use of Industrial Packages (IP). They define IP-1, IP-2, and IP-3 packages and specify, the design requirements for each. They also require the shipper to document his safety evaluation of the package design (similar to the documentation requirements for a DOT Spec 7A package).

The five regulatory defined packages allowed for the shipping of LLW and their design and testing requirements are:

1. *IP-1*; used for contaminated soils and some liquids; *satisfies the general design requirements of 49CFR Parts 173.410 and 173.411.*

2. *IP-2*; used for solid LSA-II waste; *satisfies the criteria for IP-1 plus a free-drop test specified in 49CFR173.465(c) plus a stacking test (49CFR173.465(d)).*

3. *IP-3;* used for sealed sources and irradiated hardware; *satisfies the criteria for IP-1 plus the Type A package requirements (49CFR173.412).*

4. *Type A;* used for any non-waste radioactive material greater than SCO-II, *satisfies the general design criteria plus the requirements of 49CFR17.412 plus the testing in 49CFR Parts 173.465 and 173.466.*

5. *Type B, used for waste that exceeds 1 R/hr at 3 meters; satisfies the requirements in 10CFR71.*

The following summarizes the design requirements from the relevant sections of the 49CFR173.

General Design Requirements, 49CFR173.410

1. Containers can be easily handled.
2. Container lifting attachments are capable of handling three times the container gross weight.
3. Container must be free of protrusions and easily decontaminated.
4. Design should permit no water accumulation on outer surfaces.
5. There should be no unsafe add-ons to the container.
6. Container should withstand normal acceleration and vibration and have a non-loosening closure.
7. Container contents should be compatible with container materials.
8. Container should have protected valves.
9. For air shipments:

   a. internal temperature should be less than 50°C

   b. container can survive temperature range -40°C to +55°C, and

   c for liquids, container can maintain pressure difference of 95 kPa.

Additional Design Requirements for Industrial Packages (IP), 49CFR173.411

1. IP-1 containers must satisfy general requirements of 49CFR173-410.
2. IP-2 containers must satisfy requirements for IP-1 containers; and using tests and methods of 49CFR173.465(c) and (d) and 49CFR173.461(a), demonstrate

   a. no loss of contents, and

   b. no significant increase in radiation.

3. IP-3 containers must satisfy requirements for IP-1 containers plus the requirements for Type A containers specified in 49CFR173.412.

Additional Design Requirements for Type A Packages, 49CFR173.412

1. Containers must have a substantial and easily observable seal.

2. Containers can maintain integrity with repeated temperature cycling between -40°C and +70°C.

3. Container must have a positive closure fastening device that can be opened neither unintentionally nor by pressure.

4. Container design must consider effects of waste radiolytic decomposition.

5. Package containment must withstand a reduction in ambient pressure of 25 kPa (3.6 psi). This is equivalent to an interior air pressure of 11.2 psi.

6. All valves other than pressure-relief valves must have leakage enclosures.

7. Any shield acting as radiation protection from a component must also prevent that component from escaping from the shielding.

8. A failure of a single tie-down will not impair the ability to meet the other requirements.

9. The container must, using tests and methods of 49CFR173.465(c) and (d) and 49CFR173.461 (a)-(i), demonstrate:

   a. no loss of contents, and

   b. no significant increase in radiation.

10. If the package is to contain liquids, the package must:

    a. accommodate volume and pressure changes due to temperature fluctuations,

    b. meet the tests in paragraph (i) of this section, and

    c. contain adsorbent sufficient for twice the volume of contained liquid.

Demonstrate Compliance with Tests, 49CFR173.461

Testing will be through:

1. tests of container or sample prototypes.

2. tests of samples related to demonstration of similar materials.

3. tests with models of appropriate scale.

4. calculations or reasoned arguments.

5. tests with water immersion at 38°C.

Type A Packaging Tests, 49CFR173.465

1. Packaging must withstand water spray, free drop, compression, and penetration tests.

2. Water spray test is at an equivalent rainfall of 2 inches per hour for at least one hour, then wait 2 hours before next test.

3. Free drop test:

   a. four feet for packages under 11,000 lbs gross weight; 3 feet for those between 11,000 and 22,000 lbs; 2 feet for those between 22,000 and 33,000 lb; and 1 foot for those over 33,000 lbs.

Note: An important feature of the drop test requires that the package strike the target surface at an attitude “so as to suffer the maximum damage to the safety features being tested” (e.g., for a steel drum, the locking bolt should strike the target first).

   b. for fissile material, corner drop of 1 foot.

   c. for rectangular fiberboard or wood, corner drop of 1 foot.

   d. for cylindrical fiberboard or wood, edge drop of 1 foot.

   e. drop pad is to be a flat, horizontal, rigid surface.

4. Stacking test is a compression test for 24 hours of 5 times the gross mass or 13 kPa over the entire area of the top, applied uniformly over the top and bottom surfaces.

5. Penetration test is a 1.3-inch diameter, 13.2 lb, hemispherical end bar, dropped end-on onto the weakest part of the container from a distance no less than 3.3 feet (1 meter).

Additional Tests for Type A Packaging for Liquids and Gases, 49CFR173.466

1. Free-drop test from 30 feet onto the rigid pad.

2. Penetration test-drop of bar in 173.465(c) from 5.5 feet.

Test for LSA-III Material, 49CFR173.468

1. Each solid sample must be representative of an actual solid LSA-III item.

2. The immersion test must be 7 days in water at ambient temperature.

3. The volume of water must exceed by at least 10% that absorbed or reacted.

4. The water must have a pH of 6 to 8 and a conductivity of < 10 umho/cm at 20^{o}C.

5. Activity in the water must be less than 0.1 times the A_2 value after 7 days.

Tests for Special Form Material (monolith, including package, primarily for scaled sources) 49CFR173.469

1. A different specimen may be used in each test.

2. The specimen may neither break nor shatter in testing.

3. The specimen may neither melt nor disperse.

4. After each test, the leak rate may not exceed 1.3x 10^4 atm-cm^3/s for liquids or gases.

5. Standard leak-test methods shall be used.

6. Tests:

   a. impact test shall be performed from a height of at least 30 feet.

   b. percussion testing shall be through striking equivalent to a 3-foot drop.

   c. bending test for long, slender items shall clamp one end and strike the other with a force equivalent to a drop of 3.3 feet.

   d. heat tests through heating to 800^{o}C for ten minutes.

   e. leach-assessment testing shall immerse for 7 days, heat to 50^{0}C for 4 hours, measure the activity of the water, store 7 days, re-immerse and measure the activity.

The DOT definitions of LSA waste limit the size of the package used for those wastes to 158 ft^3 or less because of the capacity limitations of the available Type B cask sizes (discussed further in Section 5). If not Type B, the container can be larger than 158 ft^3.

4 UTILITY PRACTICES AND TRENDS RELATED TO CONTAINER USE

4.1 Dry Active Wastes (DAW)

Annual volumes of utility-shipped DAW declined substantially since 1980. (References 17 and 18). Causes of this large reduction are multiple and usually driven by disposal costs. They include improvements in waste minimization, segregation, and the use of off site processing via incineration, supercompaction, and metal processing. The nuclear industry expects the volume reduction trend for DAW to continue, although at a much slower rate, since most of the existing high efficiency volume reduction techniques are already widely practiced.

Industry packaging practices for DAW have also evolved substantially over the past few years. A common practice in the 1980's was the use of 17H containers (steel drums) for packaging DAW. Metal containers were also used: B-25 (96 cubic feet) and B-12 (42 cubic feet) boxes. At that time, many utilities used on-site drum compactors or box compactors to improve packaging efficiency. Some drum compactors can achieve final densities as high as 55-60 pounds per cubic foot, although this is quite labor-intensive. Box compactors typically achieve densities of 35-50 lb/ft^3. A few plants procured super-box compactors that yield final compaction densities of 50-60 lbs/ft^3. Today, on site compaction is rarely economical, giving way to higher efficiency processes.

In the mid-1980's, supercompaction of 52-gallon and 55-gallon drums into "hockey pucks" and placement in overpacks became a common practice. By 1995, most plants were shipping bulk DAW in sea-land containers to off site processors, where it is sorted for decontamination, supercompaction or incineration. Final waste densities of 60 to70 lb/ft^3 is typical for compacted waste residuals, and incineration achieves volume reduction ratios of 50:1 or better (based upon the as-generated volume).

Most off-site vendors condition (process) waste from one or more utilities into a single container to obtain the best packaging efficiencies. In the event that a utility is forced to store its waste on-site, it is likely that these commingling practices will change substantially.

Grit blasting is the most common vendor decontamination practice. Decontaminated material, verified to be free of any radiological hazard, is either released for scrap, returned to the utility, or buried in a local land fill. Metal that is not economical to decontaminate is often melted into solid ingots for recycle as shielding. In the event of LLW disposal site closure, the contractor will return all conditioned (processed) waste containers to the utility for storage and ultimate disposal. Utilities and suppliers expect no particular difficulties from regulators from this procedure and container usage, other than a possible requirement by some disposal sites to solidify incinerator ash (Section 4.4).

4.2 Wet Solid Wastes

Annual disposal volumes of wet solid wastes also have decreased substantially since 1980 (References 17 and 18). The largest reduction is from BWRs that have reduced or stopped regenerating bead-resin from demineralizers and, thus, drastically lowered the volumes of waste evaporator concentrates. Many plants have ceased using waste evaporators. Other reductions resulted from more efficient use of resins and better segregation of liquid wastes. Most recently, steam reforming has made a substantial contribution to reducing disposed resin volume.

As with DAW, it appears that the volume trend may have nearly leveled off in 1990. Typical annual generated wet waste volumes that will likely require interim storage capacity may be in the range of <2500 ft^3 for BWRs and <500 ft^3 for PWRs.

4.2.1 Bead and Powdered Resins

Resins constitute the bulk of wet solid waste generated, representing over half of the Class B and C waste generated by PWRs, and nearly all of the Class B and C waste generated by BWRs (References 17 and 18). At the present time, the volume of the higher-activity resins generated by both PWRs and BWRs is about 180-195 ft^3 per year. This volume has become relatively constant over the past several years although aggressive programs were being implemented in 2002 at some stations to reduce Class B and C waste volumes.

Utilities typically dewater resins, placing Class A material in steel liners and Class B or C material in high integrity containers (HICs) (Reference 18). The liners used for Class A materials are cylindrical containers of heavy gauge carbon steel, lightly coated or painted, and generally range in size from 120 to 210 ft^3.

The HICs used for Class B and C wastes are also right-circular cylinders. However HICs require special materials and construction to certify the container to meet the stabilization criteria for these two higher activity waste classes. Most of the currently used HICs are of a high-density cross-linked polyethylene (HDPE), although some utilities use a stainless steel alloy or a polyethylene-lined stainless steel HIC; a couple of plants still use ferralium HICs.

4.2.2 Evaporator Bottoms and Sludges

Evaporator bottoms and sludges are almost always Class A material, and the disposal regulations require their solidification (Section 3). Utilities with evaporator concentrates typically use 1A2 drums (7.5 ft^3) or steel liners (120-160 ft^3) and solidify the wastes with concrete. Sludges are usually treated in similar fashion (Reference 18). Solidification in liners with an NRC approved binder would satisfy the stability requirement even for higher-classification wastes.

4.2.3 Filter Cartridges

PWRs are the dominant user of process-stream filter cartridges. Those used in the reactor coolant letdown system become very radioactive and are almost always Class B or C waste. Typical volumes of the higher-activity filter cartridges in a PWR are about 125 ft^3 per plant per year (Reference 18). Volume generation rate is relatively constant.

Plants dispose of the cartridges through three means:

1. A couple of plants mix the filters with dewatered resins in a HIC, using the resins for some radiation shielding for the highly radioactive filters. Due to ALARA considerations, this practice is no longer common.

2. Most plants place dewatered high activity cartridges in a HIC by themselves, surrounded by absorbent material.

3. Other plants encapsulate the filters with grout in a concrete-lined container.

The HIC size for the first two disposal methods is generally limited to 120 ft^3 in order to use the more heavily shielded shipping casks for transport. This is necessary, as the containers frequently have a contact dose exceeding 100 R/hr. A growing trend over the past few years is the use of filter shredders or filter shears to improve waste container packaging efficiency. In addition, the introduction of nonmetal filters for high activity wastes has opened the door to conversion reforming of filter wastes for greater volume reduction. Utilities use a variety of containers for filters, including stainless steel alloy and HDPE HICs, as well as concrete-lined steel liners. (Many utilities compact low activity filters into steel drums.)

4.2.4 Oils

Prior to 1990, contaminated oil was most commonly disposed in 17H drums after being either absorbed or stabilized (References 17 and 18). Since 1990, burial of this material has nearly stopped. Most utilities now either decontaminate the oil on-site or ship it to an off-site vendor for incineration or for heat recovery.

4.3 Stabilization Processing

The selection of waste containers is dependent upon the chosen waste stabilization methods. A principal issue applies to spent resins where the choice may be either dewatering in a HIC or solidification in a liner. Both choices present challenges to interim storage. Dewatered resins may disintegrate, producing gas and corrosive chemicals. Difficulties may also result if waste transfer to another container for solidification is required at a later date. With solidification, the risk is that the solidification media may not be accepted at the future disposal site at the time of disposal. These issues are briefly discussed in this subsection and in greater detail in Volume 5 of the EPRI Interim On-Site Storage of LLW series of reports (Reference 2).

4.3.1 Solidification

The principal concern in choosing and using a specific stabilization method is its ultimate acceptability at the disposal site. Non-acceptance would require repackaging through reprocessing of the solidified waste or through the use of acceptable overpacks. The former method may not be practical. It is laborious and presents substantial ALARA concerns. Overpacks result in additional expense for the containers and increased volume at the disposal site.

There are four instances where refused acceptance of the container could occur:

1. container failure through corrosive or mechanical breaching;

2. use of a solidification media known to be unacceptable; or

3. withdrawal of a media acceptance after its use by the utility, or

4. rehydration of ion exchange media or free-standing liquid (requiring further dewatering before disposal).

Disposal site certifications for existing sites are presently in place for various forms of cement, cement/gypsum, bitumen, and vinyl-ester-styrene (DTI process or DOW media, and GE polymer stabilization). Note that NRC-approval is not required for solidification media, just as it is not required for waste containers. However, the generator risks rejection of waste forms if the waste forms or HICs are generated outside the NRC's topical evaluation report review process. For example, Hanford and Barnwell both accept NRC-approved stabilization processes and containers. Envirocare does not recognize stable waste forms at this time at their Class A trench, and no Class B or C trench is approved under the existing license.

A related concern for solidified waste is that the small concentration of allowed liquid (<0.5%) could collect as a free standing liquid outside the solidified monolith but within the waste container. The potential for this increases under repetitive freeze/thaw cycles. This phenomenon is considered a minimum risk in well-solidified waste; however, the potential exists for the fractured resin to leach and concentrate chemicals from the matrix, thereby producing internal container corrosion.

Cement solidification of resins has presented some problems in the past, and experience with the DTI process and bitumen (for resins) is presently limited in the US commercial nuclear industry. From an international perspective, France and India solidify resin in polymer. An "advanced polymer process" is now offered in the USA; the US Navy uses the process, and Diablo Canyon has used it successfully. The process is under review by the CRCPD E-5 Committee for a national approval by the States (as opposed to approval by the Federal government).

Encapsulation of filters in a solidification media is a routine and relatively easy process, and it should present no particular processing problems (assuming an approved media is used). EPRI has reported the advantages of cement encapsulation and polymer encapsulation of cartridge filters to immobilize C-14 (report number TR-1003066, Reference 55.) The VERI Encapsulation Polymer encapsulation process was the last topical report approved by the NRC prior to discontinuing their approval program. In addition, one cement encapsulation process has been approved by South Carolina DHEC and has been submitted to the CRCPD E-5 Committee for a national approval by the other States. Table 4-1 lists the currently approved stabilization binders and the approving authority.

(Note that Envirocare of Utah does not accept cartridge filters which have been encapsulated and characterized using concentration averaging in their Class A trench. Their proposed license amendment for a Class B and C trench would allow concentration averaging and averaging the activity over a stable encapsulation agent, unlike Barnwell and Hanford. This will be a significant benefit to waste generators if and when a Class B and C trench is approved. See section 3.2.3 for further discussion.)

Table 4-1
Approved Stabilization Binders

Binder (Supplier)	NRC Topical Report	CRCPD E-5 Committee	South Carolina DHEC
Spent Resin Stabilization Binders			
Aztec (GE)	Yes	N/A	Yes
VES (DTI)	Yes	N/A	Yes
VERI (DTI)	Yes	N/A	Yes
Advanced Polymer (DTI)	N/A	Yes	Yes
Encapsulation Stabilization Binders			
VERI Encapsulation (DTI)		N/A	Yes
Cement (RWE Nukem)	N/A	Yes	Yes
Cement (Duratek)	N/A	Not Submitted	Not Submitted

4.3.2 Dewatered Resins and Filters

Extended interim storage of dewatered resins and filter cartridges may create some problems for utilities. Biodegradation can release quantities of methane gases. These must be well vented from the container and the storage area and could cause swelling in the container.

Degradation could also result in corrosive chemical byproducts and create a product that is difficult to transfer to another container or to solidify. Since many of the proposed compact sites intend to require solidification of all wastes, the resins and filters would either have to be solidified at the time of storage or when the waste is shipped for disposal. Solidification of degraded material could be difficult, either when done in the same container or after a potentially difficult slurry-transfer to another container. Further, some of the current containers have welded lids that would require cutting to remove. This could create personnel exposure or facility contamination hazards.

Liquids remaining in a container of dewatered waste could also collect as free standing liquid. This was reported by several utilities after as little as a one-year storage period. Over an extended storage period free standing liquids could leach or concentrate corrosive chemicals to impair the container integrity or cause degradation to any dewatering internals.

Undegraded cartridge filters may be transferred by the technique known as “fishing" (i.e., using a pole and hook to snare a filter for transfer between containers). However, cartridge filters, particularly those of organic material, could disintegrate and create transfer problems. Methods for transferring severely degraded cartridges are unknown.

4.4 Solidification Methods for Incinerator Ash (Reference 19)

Some state compacts have proposed acceptance of incinerator ash only if stabilized against possible dispersion. Ash may be stabilized through solidification within the present container. The typical solidification media would be an epoxy binder, concrete, or a glassification process. Alternatively, stabilization could be accomplished through use of a concrete overpack. A incinerator contractor reported that the waste loading factor for incinerator ash solidified with concrete was 12% and, for the epoxy binder or glassification, 33% (Reference 19).

5 CURRENTLY AVAILABLE CONTAINERS

Commercially available waste containers come in a variety of sizes, configurations and construction materials. Some of the boxes, drums, liners and other containers used by utilities may not meet the DOT industrial packaging (IP-2) criteria or may not be adequate for extended periods of interim storage. Boxes and drums for DAW are made of carbon steel, some of which have IP-2 ratings. Containers for DAW are available from a relatively large number of suppliers, some of whom are local to the user.

Liners, usually larger, are available from a smaller number of suppliers located primarily in the southeast portion of the U.S. Most liners are not IP-2 qualified. High integrity containers, which are typically available from the same suppliers as the liners, also come in several sizes to suit the waste, activity, volume, loading and shipping requirements. They are available in several construction materials of which high-density polyethylene is currently the most common.

Waste in liners and HICs is usually shipped in casks. When shipped in a cask, the inner containers do not require DOT certification. Shipping casks are usually supplied at the time of shipment by the waste transporter. They are of various sizes and come with different wall thicknesses as radiation shielding requires.

On-site storage modules are available for wastes that require additional radiation shielding for interim storage. They are built of reinforced concrete and are suitable for outside storage.

The waste packager must consider the radiation level of the container as part of their container selection process to assure that a shipping cask is available with adequate shielding and capacity. There are various computer codes (Reference 22) to aid in this selection. This section summarizes data collected on existing commercially available LLW containers, on-site storage modules, and shipping casks.

5.1 Waste Boxes and Drums

Table 5-1 lists some typical containers that utilities use to package waste for disposal. Most of these containers are welded together from sheet carbon steel, and the Table lists the typical thickness of the steel. The drums are the common 55-gallon cylindrical drums, which are available in varying gauge wall thicknesses. Boxes are most commonly 12 or 14 gauge with rectangular cross sections.

Table 5-1
Typical Commercial Dry Active Waste Containers

	Container Designation	Disposal Volume (Cubic Feet)	Wall Thickness	Dimensions (Inches)	Loading
DRUMS	1A2	7.5	18 Gauge	22.4 Dia x 32.3	Top
	1A2	7.5	16 Gauge	22.4 Dia x 32.3	Top
	1A2	7.5	14 Gauge	22.4 Dia x 32.3	Top
	Overpack	10.8	18 gauge	25.5 Dia x 36.5	Top
	Overpack	12.1	18 gauge	27.5 Dia x 38.5	Top
BOXES	B-25	96	10, 12,14 Gauge	44x47x73	Top
	B-12	48	12,14 Gauge	24x47x73	Top
	SEG-35	103.2	12,14	52x47x73	Top
	Innerpack	38.5	16 Gauge	42x33x48	Top
	Overpack	44.1	12 Gauge	46x36x48	Top
	Sea-Land	1280	NA	96x96x240	End, Top
	Sea-Land	2560	NA	96x96x480	End, Top
SHIELD BOXES	Shield Box (Also a van)	428.0	0.5" Lead Equivalent	100x86x86	Top
	Shield Box (Also a van)	411.5	0.66" Lead Equivalent	234x39x78	Top

Some DAW containers may also have a Type A or IP-2 pedigree, as discussed in Section 3. These containers are available from many sources, some of which may be local to the plant. This saves on shipping costs for the empty new containers. Major waste brokers and contractors also supply Type A containers and IP-2 boxes and drums. It is essential that shippers of DOT Spec 7A or IP packages maintain on file documentation of the safety analysis for their own specific package and contents.

B-series boxes and 1A2 drums are normally coated with either a primer and enamel or epoxy paint. Closure of the drum lids includes a gasket and bolt for security. Most boxes, on the other hand, use gaskets and external closure clips. The trend in DAW packaging has shifted from heavy use of 1A2 drums to extensive use of B-25 boxes.

Utilities also use 1A2 drums for solidified evaporator concentrates and sludges, although respondents to a 1991 survey preferred steel liners for this purpose (Reference 18). The volume of solidified evaporator concentrates has declined substantially over the past decade as fewer utilities use waste evaporators.

Utilities also use sea-land containers for bulk DAW shipments to off site processors. These are available in two sizes, 1280 and 2560 ft^3 (20 and 40 ft long), to collect and transport DAW to the processor, but they normally are not used as disposal containers by commercial nuclear plants. (Some DOD and DOE waste generators dispose of DAW in sealed, strong-tight sea-land containers.) Some supercompactors compress 17H drums and place them in overpacks which are typically coated only with a primer and enamel paint. If the waste is incinerated, the compressed ash is generally placed in a steel box. One off site processor uses a steel container ("outer pack") for both supercompacted and incinerated waste. An epoxy paint coats the exterior of these outer packs.

5.2 Steel Liners

A liner is an IP-2 right-circular cylinder. It is available in various sizes, constructed of carbon steel, about 1/4 to 1/3-inches thick. It is usually painted internally with layers of a primer paint and externally with an enamel or epoxy paint (thickness of 0.002 to 0.003 inches) to inhibit corrosion. They are all top loading with openings typically smaller than the liner diameter.

Vendors supply optional disposable internal mixing devices for cement solidification of concentrates, sludge, or resin wastes in the liners. Liners can also be fitted with dewatering internals containing small-particle filtration systems. Liners are currently used for dewatered Class A unstable resin. They are also used for solidified Class B and C resin in polymer and for encapsulation of Class B and C filter cartridges (Reference 18). Many dewatering systems contain internal underdrains, compression bags, and level indicators to assist in the dewatering process.

The smaller liners have full-opening tops, whereas the larger liners have top opening diameters for filling and processing ranging from about 10-inches to about 25-inches. Openings on liners that contain built- in mixing systems typically have the larger diameter. Lids are bolted, clipped, or snapped over the opening. Liners of dewatered waste should allow for easy re-opening after a few years storage. If closed with spring-back snaps, they must be drilled out to reopen the liner. Some of the newer designs are available as reusable liners and have multiple access ports.

Some liners have passive devices in the top for venting of gases. The passive vents are usually 0.75-inch diameter plugs of stainless-steel containing a carbon-carbon absolute filter (99.97% for 0.03 micron particles). All liners have either grappling rings or lifting eyes for handling by cranes, and some have attached slings, although some have multiple lifting configurations.

Liners can usually be stacked to a minimum of two high, even for the large units. If stacking above this height is desired, the user should perform an engineering analysis that includes the weight and stability of the contents to determine the stacking limits.

Table 5-2
Typical, Commercially Available Disposal Liners

Supplier	Container Designation	Internal Volume (ft3)	Diameter (inches)	Height (inches)	Port Opening (inches)	Disposal Volume (ft3)	Gross Weight (pounds)
DURATEK	1-13	14.6	25.0	51.4	25.0	15.5	5,000
DURATEK	1-13 insert	6.2	19.3	43.8	25.0	15.5	5,000
DURATEK	3-55	54.0	34.0	109.3	31.0	57.4	7,800
DURATEK	6-80	84.0	58.0	57.0	22.0	87.2	9,900
DURATEK	7-100	96.0	74.5	40.0	22.0	100.9	10,800
DURATEK	8-120	121.0	61.0	74.0	22.0	125.2	14,500
DURATEK	14-170	173.0	74.5	73.3	22.0	180.1	20,700
DURATEK	14-195	200.0	76.0	79.0	22.0	207.4	23,250
DURATEK	21-300	320.0	82.0	108.0	22.0	330.1	27,250
RWE.NUKEM	ES-50	49.3	47.3	51.0	25.0	52.0	4,200
RWE.NUKEM	ES-142	122.2	63.5	69.8	25.0	128.3	10,000
RWE.NUKEM	ES-190	162.4	72.5	71.0	25.0	170.2	16,800
RWE.NUKEM (1)	ES-210	191.0	74.8	78.3	25.0	199.4	18,000
RWE.NUKEM (1)	ES-210	191.0	74.8	78.3	25.0	199.4	20,000
RWE.NUKEM (1)	ES-210	191.0	74.8	78.3	25.0	199.4	25,000
RWE.NUKEM (2)	7-100	89.2	74.25	38.5	70.25	93.13	13,000
RWE.NUKEM (2)	10-142	117.0	65.0	68.0	22.5	128.6	26,000
RWE.NUKEM (2)	190	164.5	72.8	69.5	26.0	180.68	16,800
RWE.NUKEM (2)	210	186.0	75.0	75.5	22.5	202.0	20,000
STUDSVIK	TL-120	113.9	61.0	71.0	20.5	128.1	14,000
STUDSVIK	TL-215	197.9	76.0	79.0	20.5	207.4	19,000

(1) The key difference among the three RWE.NUKEM ES-210 liners are the gross weight and the lifting arrangement. In the order listed above, the three lifting arrangements are: 3-point @ 45 degrees; 3-point @ 60 degrees; 4-point @ 60 degrees.

(2) RWE.NUKEM liners can be constructed of either carbon or stainless steel. They also can be assembled for reuse (i.e., a reusable liner) with multiple watering ports.

A concrete-lined container has a preformed concrete insert inside a standard liner. It is 6.3-inches thick on the sides and 11-inches thick on the top and bottom. No topical report was submitted for this container (Reference 19), and it is considered a liner by its supplier. The waste media intended for the concrete-lined containers is solidified filter cartridges. Table 5-2 is a tabulation of common commercial liners used in LLW disposal. These data came from a combination of sources, including utility surveys (Reference 1 and 2) and vendor literature and surveys (References 11, 12, 19 and 23-25).

5.3 High Integrity Containers (HICs)

HICs are containers that meet the waste stability requirements of 10CFR61 by themselves for Class B and C wastes and do not depend upon the waste within for any structural stability. HICs have circular cross sections and often have hemispherically shaped (rounded) tops and bottoms. Filling and process access are from the top, which is fitted with a rigid seal after filling. The containers are typically DOT Type A packages. They usually have grappling slings built into them or have lifting eyes for attaching to slings.

HICs are constructed from several materials to meet the requirements to withstand the severe chemicals radiation and structural environment for the required minimum 300-year lifetime of the package. Containers approved for disposal have been tested according to the procedures and acceptance criteria discussed in Section 3.

Containers currently approved by the NRC (Reference 26) are a reinforced, concrete-lined steel container, a polyethylene-lined stainless steel container, and a stainless steel container. As with liners, suppliers offer optional internal mixing and various dewatering systems with the HICs, depending on the desired use. Fill- and processing-port openings on the top are similar to those for the liners and range from a full top access for the smaller containers to 10 to 24 inch openings for the larger HICs.

HICs are required to have passive venting mechanisms built into the containers to release any internal radiological or bacteriological gas buildup. Most vents are carbon-carbon absolute filters screwed or epoxied into the lid of the container. Utilities use HICs mostly for Class B or C dewatered resins or filter cartridges. HICs can also be stacked at least two high. (A flat spacer pad is required for HICs that have rounded tops.) As with liners, stacking higher than this should require an engineering analysis.

NRC-Approved HICs

HICs are also constructed from other materials and Table 5-4 presents a compilation of data for the available HIC designs from materials other than polyethylene. The PIC-HIC is a steel-fiber reinforced and polymer impregnated concrete-lined container (References 23 and 26). The smaller outer steel casing is a 17H drum. The thickness of the concrete is about 3 cm on the radius (sides) and about 4 cm on the ends (top and bottom). Venting is through a sintered ceramic plug fastened with epoxy into the concrete lid. A PIC-HIC topical report was approved by the NRC (Reference 26). However, the PIC-HIC is not widely used in the U.S. for radioactive waste.

Ferralium is a high-chromium content stainless steel with excellent corrosion resistance (Reference 23). Smaller models have 3/8-inch thick walls and 24-inch diameter top openings, whereas the larger containers have 1/2-inch thick wall; all have internal stiffeners. Closure of the seals is through bolting against a silicon-rubber gasket. Bolt-closed containers should open easily after storage. The carbon-carbon passive vents will breathe sufficiently to prevent gas build up inside the container. Lifting eyes are attached to the container top. A topical report on Ferralium HICs has been approved by the NRC (Reference 26), and the containers are approved by the existing disposal sites. Ferralium HICs are very expensive to produce and purchase, so they are not widely used. Ferralium HICs can easily be stacked two high.

There is a series of HICs that have a HDPE inner liner molded into a stainless steel shell. In this report, they are referred to as poly-lined stainless steel HICs. The containers have a hemispherical top with a dish-shaped bottom to aid in dewatering. Fill-port openings are 16.5 inches in diameter. Closure is by a ring-clamped polyethylene lid, covered by a stainless steel lid, bolted on. The passive plug vents are placed in the lids of the containers to prevent gas build up inside the container. Lifting eyes are attached to the container top. A topical report on polyethylene-lined stainless steel HICs has been approved by the NRC (Reference 26), and the containers are approved by the existing disposal sites. Because of their rounded tops, these HICs require pads for stacking.

A full series of fiberglass composite HICs was offered by one supplier in the 1980’s and early 1990’s. Although fiberglass HICs were included in the original version of this report, all fiberglass HICs have been discontinued.

Polyethylene HICs

HDPE HICs have not been approved by the NRC because of concerns over their long-term structural integrity, as discussed in Section 7. The existing disposal sites permit them only when placed in concrete overpacks. Polyethylene HICs without structural supports can be stacked with the use of spacer pads. Ultraviolet radiation deteriorates polyethylene, and the packages must be protected by coverings and not exposed to direct sunlight. Table 5-3 lists the available HDPE HICs.

High-density, highly cross-linked polyethylene (HDPE using Marlex-200) is the construction material for the most widely used high integrity containers, and there are four principal suppliers (References 19 and 23-25). Typical wall thicknesses of polyethylene HICs are 1/2 inch, and walls are molded with stiffening ribs. Vessels may be obtained with flat, conical or corrugated bottoms, allowing for ease in dewatering different media. Closure typically uses double rubber gaskets or seal plates with the polyethylene plug screwed into place. Thus, re-opening the containers after a few years storage should not be difficult. Lifting mechanisms are slings or baskets external to the container.

As with other HICs, HDPE HICs may be stacked at least two high. However, grappling and attaching slings to some HDPE HICs can be a challenge. As a solution, vendors offer a “stackable, grappable” support structure (steel frame) that fits around the HIC and provides sufficient structural integrity for easy stacking and grappling.

Sizes cover a wide range, with the smaller units being most often used for the highly radioactive filter cartridges (Reference 15). Each HIC fits a limited number of shipping casks, and the size HIC used for a given waste stream often depends upon the required cask (i.e. the amount of radiation shielding required for transport).

Table 5-3
Commercially Available HDPE High Integrity Containers

Supplier	Container Designation	Internal Volume (ft3)	Diameter (inches)	Height (inches)	Port Opening (inches)	Disposal Volume (ft3)	Gross Weight (pounds)
DURATEK	60G-Over	8.4	25.5	34.5	18.3	10.2	1,200
DURATEK	Small Over	25.0	34.0	56.5	26.0	28.0	2,500
DURATEK	146G Over	33.5	34.0	74.3	26.0	36.5	2,500
DURATEK	Medium Over	35.0	34.0	78.0	26.0	38.3	2,500
DURATEK	6-80	73.3	57.0	56.5	22.5	83.4	5,000
DURATEK	8-120	107.6	61.5	73.5	22.5	120.3	10,000
DURATEK	10-160C	129.8	65.5	76.3	22.5	145.8	16,000
DURATEK	10-160N	125.4	64.5	76.3	22.5	141.0	9,500
DURATEK	14-170	150.3	74.5	71.5	22.5	170.8	10,800
DURATEK	14-195	171.5	75.0	79.5	22.5	194.1	12,200
DURATEK	14-215	189.2	76.0	79.5	22.5	205.8	13,000
DURATEK	21-300	285.1	81.0	108.5	22.5	314.1	18,750
RWE.NUKEM	EL-50	41.0	47.0	51.0	19.8	51.2	4,200
RWE.NUKEM	EL-142	113.6	64.5	70.0	19.8	132.4	8,250
RWE.NUKEM	EL-190	150.6	73.5	71.0	19.8	174.3	11,950
RWE.NUKEM	EL-210	176.7	75.5	78.0	19.8	202.1	13,000
RWE.NUKEM	Radlok-55	6.0	23.5	35.3	22.5/8.3	8.9	1,000
RWE.NUKEM	Radlok-200	57.5	51.9	60.4	16.0/8.3	73.4	5,500
RWE.NUKEM	Radlok-500	111.0	64.5	71.9	16.0/8.3	135.8	9,500
RWE.NUKEM	Radlok-100	125.7	71.1	71.0	16.0/8.3	163.3	10,500
RWE.NUKEM	Radlok-179	156.8	73.5	72.9	24.3/10.2	179.4	18,500
RWE.NUKEM	Radlok-195	172.8	73.5	79.5	24.3/10.2	195.7	18,500
RWE.NUKEM	NUHIC-55	14.8	31.5	43.6	27.5	18.8	1,800
RWE.NUKEM (1)	NUHIC-80B	68.4	55.0	54.6	22.5	74.9	6,600
RWE.NUKEM	NUHIC-80B	66.7	55.0	53.3	19.8	73.2	6,600
RWE.NUKEM (1)	NUHIC-90	80.0	69.8	40.5	16.0	89.5	4,800
RWE.NUKEM	NUHIC-90	78.3	69.8	38.5	19.8	84.7	4,800
RWE.NUKEM	NUHIC-120	105.8	60.0	73.0	19.8	122.5	11,865
RWE.NUKEM (1)	NUHIC-136	127.0	65.0	71.0	22.5	136.3	8,500
RWE.NUKEM	NUHIC-136	125.3	65.0	69.5	19.8	133.5	8,500
RWE.NUKEM (1)	NUHIC-158	140.0	69.8	72.3	22.5	158.1	8,500
RWE.NUKEM	NUHIC-158	138.3	69.8	70.5	19.8	155.9	8,500
RWE.NUKEM	NUHIC-205	181.0	75.3	78.0	19.8	204.8	20,000

(1) These RWE.Nukem HICs do not have a recessed lid.

Table 5-4
Commercially Available NRC-Approved High Integrity Containers

Supplier	Container Designation	Internal Volume (ft3)	Diameter (inches)	Height (inches)	Port Opening (inches)	Dispos al (ft3)	Gross Weight (pounds)
CARBON STEEL AND POLY-IMPREGNATED CEMENT							
CHICHIBU	PIC-HIC (1)	5.6	20.4	35.3	20.4	7.5	500
CHICHIBU	PIC-HIC	7.5	22.6	29.5	22.6	10	680
CHICHIBU	PIC-HIC	10.9	25.2	32.4	25.2	25.2	1000
CHICHIBU	PIC-HIC	14.8	28.1	41.1	28.1	20	1350
HIGH-CHROMIUM STAINLESS STEEL (FERRALIUM)							
RWE.NUKEM	EA-50-A	44.9	46.5	50.8	24.0	49.9	4,200
RWE.NUKEM	EA-50-C	42.4	46.5	50.8	44.1	49.9	4,200
RWE.NUKEM	EA-142-A	120.9	64.0	70.3	24.0	130.8	10,000
RWE.NUKEM	EA-142-C	109.2	64.0	70.3	61.1	130.8	10,000
RWE.NUKEM	EA-140-A	122.6	64.0	71.3	24.0	132.7	15,000
RWE.NUKEM	EA-140-C	111.1	64.0	71.3	61.6	132.7	15,000
RWE.NUKEM	EA-190-A	163.2	73.5	71.6	24.0	175.9	20,000
RWE.NUKEM	EA-190-C	147.9	73.5	71.6	71.1	175.9	20,000
RWE.NUKEM	EA-210-A	188.5	75.3	78.5	24.0	202.0	20,000
RWE.NUKEM	EA-210-C	175.0	75.3	78.5	72.9	202.0	20,000
POLYETHYLENE-LINED STAINLESS STEEL							
RWE.NUKEM	C-96	72.5	74.5	39.0	22.6/16.5	98.1	12,000
RWE.NUKEM	C-118	100.4	60.0	74.0	22.6/16.5	121.2	14,000
RWE.NUKEM	C-131	114.3	64.5	71.0	22.6/16.5	134.6	10,000
RWE.NUKEM	C-179	158.2	74.5	72.5	22.6/16.5	182.4	14,000

(1) This is the only PIC-HIC model still available in the United States, although all four models are NRC-approved containers.

5.4 On-Site Storage Modules

Several utilities use on-site storage modules to provide adequate radiation shielding of HICs and liners containing Class A, B and C wastes for short term storage. These modules might also be used for extended, interim storage and are usually designed for outside storage applications.

Construction is of reinforced high-density concrete with optional epoxy coatings applied to internal or external surfaces, They also employ internal polyethylene or stainless-steel catch basins or linings and drains. Scaling of the lid uses a venting "O-ring" seal, and both the cask and its lid have lifting lugs.

A typical volume for a storage module is about 200 ft^3 which will hold either a large liner or HIC or several smaller containers. However, some plant-specific designs are substantially larger and can hold multiple large liners or HICs. They are available with different shielding thicknesses for various needs. A concrete thickness of 24 inches has an equivalent lead shielding thickness for ^{60}Co radiation of about 4 inches giving an attenuation factor of about 1000. Table 5-5 lists typical commercially available on-site storage modules (References 11, 12, 19, 23, 24 and 31). The Table includes the attenuation factor of the container walls for ^{60}Co.

5.5 Shipping Casks

Shipping casks are usually leased, although some utilities have purchased their own. Requirements for radiation shielding of the cask and its availability play a significant role in the selection of waste containers. Tables 5-6 and 5-7 present a listing of typical commercially available Type A and Type B shipping casks, respectively. Listed are the internal volumes and dimensions, along with the shielding wall thickness (in units of equivalent lead thickness) to equal the stopping power for ^{60}Co radiation. As indicated in Table 5-7, because of the required shielding of the Type B casks and transportation load restrictions, internal volumes of these casks are limited.

Table 5-5
Commercially Available On-Site Storage Modules

Supplier	Container Designation	Interior Volume (ft3)	Interior Diameter (inches)	Wall Height (inches)	Cask Thickness (inches)	Co-60 Attenuation Factor	MODULE Weight (pounds)	External Volume (ft3)
Cylindrical Modules								
ATCOR (DURATEK) (2)	1-11	11.0	26.0	39.0	15.0	286	13,820	98.3
ATCOR (DURATEK) (2)	7-100	85.0	78.1	40.0	13.1	141	49,400	348.6
ATCOR (DURATEK) (2)	8-120	126.0	63.0	76.0	23.0	4845	93,300	676.5
ATCOR (DURATEK) (2)	14-195	200.0	78.1	80.0	13.1	141	70,800	546.2
DURATEK	RADVAULT-140	150.0	66.0	76.0	24.0	4845	94,000	632.0
DURATEK	RADVAULT-215	221.0	78.0	80.0	16.0	286	103,400	655.7
DUFRANE	DNSI-14-200-S	221.2	78.0	80.0	16.0	286	57,000	583.0
DUFRANE	DNSI-14-200-M	221.2	78.0	80.0	19.5	65	74,000	696.8
DUFRANE	DNSI-14-200-L	221.2	78.0	80.0	13.0	987	44,155	511.3
DUFRANE	DNSI-14-200-H	221.2	78.0	80.0	23.0	3402	87,400	803.7
DUFRANE	DNSI-8-120-S	150.5	66.0	76.0	22.0	286	71,000	605.0
DUFRANE	DNSI-8-120-H	150.5	66.0	76.0	25.0	(1)	85,600	703.1
SEG (RWE.NUKEM) (3)	PROCESS SHIELD	210.0	102.5	105.5	12.3	76	40,240	632.0
SEG (RWE.NUKEM) (3)	PROCESS SHIELD	210.0	108.0	111.0	15.0	201	52,330	632.0
SEG (RWE.NUKEM) (3)	PROCESS SHIELD	210.0	118.5	121.5	20.5	1405	78,960	632.0
SEG (RWE.NUKEM) (3)	PROCESS SHIELD	210.0	113.0	116.0	17.5	487	64,400	632.0

Table 5-5 (Continued)
Commercially Available On-Site Storage Modules

Supplier	Container Designation	CAVITY Volume (ft3)	CAVITY Dimensions (Inches)	WALL Thickness (inches)	Co-60 Attenuation Factor	MODULE Weight (pounds)	External Volume (ft3)
Rectangular Modules							
DURATEK	RADVAULT 825	485.3	77x99x110	5.5	7.0	36,000	703.0
DUFRANE	DNSI-SV-1000	1004.5	84x84x246	8.0	8.3	93,500	1607.2
DUFRANE	DNSI-SV-1300	1296.0	108x108x192	6.0	8.3	71,600	1756.7
DUFRANE	DNSI-SV-1500	1530.0	108x120x204	6.0	8.3	95,400	2145.0
SEG (RWE.NUKEM) (3)	SQ-1	158.0	84x56x61	6.0	8.3	18,000	253.1
SEG (RWE.NUKEM) (3)	SQ-2	158.0	84x56x61	3.0	2.9	9,000	206.7
SEG (RWE.NUKEM) (3)	SQ-4	464.0	110x88x126	6.0	8.3	35,000	506.7
Hexagonal Modules With Cylindrical Cavity							
SEG (RWE.NUKEM) (3)	SUREPAK SP-1	218.3	77.0D x 81.0	3	2.9	16700	319.3
SEG (RWE.NUKEM) (3)	SUREPAK SP-2	218.3	77.0Dx81.0	15	201	69800	749
SEG (RWE.NUKEM) (3)	SUREPAK SP-3	218.3	77.0D x 81.0	22	2389	90700	798

(1) Attenuation factor not available for the Dufrane DNSI-8-120-H module (new module; attenuation not yet evaluated by Dufrane).

(2) These modules were produced by ATCOR. The design is currently owned by Duratek. These modules are sometimes sold between nuclear stations with ATCOR markings on the module, so both names are included in this table.

(3) These modules were produced by SEG. The design was later purchased by RWE.NUKEM. These modules are sometimes sold between nuclear stations with SEG markings on the module, so both names are included in this table.

Table 5-6
Commercially Available Type A (IP-2) Shipping Casks

Supplier	Container Designation	Internal Volume (ft-3)	Internal Diameter (Inches)	Internal Height (inches)	Lead Equivalent Shielding (inches)	Loaded Cask Weight Limit (pounds)
DURATEK	6-80-2	91	59	58	5	44,000
DURATEK	8-120 A	131.0	62.0	75.0	4.5	69,300
DURATEK	14-190 H	185.0	75.3	73.4	3.5	45,200
DURATEK	14-170 Series II	185.0	75.5	73.3	2.1	33,800
DURATEK	14-170 Series III	185.0	75.5	73.3	2.1	35,200
DURATEK	14-195 H	215.0	77.0	80.1	2.7	39,650
DURATEK	14-215 H	215.0	77.0	80.3	2.7	38,400
DURATEK	21-300	340.0	83.0	109.3	1.5	30,200
DURATEK	21-300 w/insert	170.0	76.3	106.5	2.0	39,310
RWE.NUKEM	LN-14-170	190.8	75.5	73.6	2.8	53,000
RWE.NUKEM	50-2.5L	56.1	48.5	52.5	2.8	19,325
RWE.NUKEM	14/190 M	190.1	75.5	73.4	2.6	53,500
RWE.NUKEM	14/190 L	190.1	75.5	73.4	2.1	49,200
RWE.NUKEM	14/190 H	190.1	75.5	73.4	3.5	65,200
RWE.NUKEM	14D-2.0	190.1	75.5	73.4	2.6	48,000
RWE.NUKEM	14-210 H	217.7	77.3	80.3	2.8	58,400
RWE.NUKEM	14-210 H (2” insert)	217.7	66.0	71.0	3.5	58,400
RWE.NUKEM	14-210 L	217.7	77.3	80.3	2.1	51,600
RWE.NUKEM	14-210 L (2” insert)	217.7	66.0	71.0	4.2	51,600
RWE.NUKEM	10-142 A	142.5	66.0	72.0	4.6	64,000
RWE.NUKEM	HN-190-2	190.1	75.5	73.4	2.6	48,000
RWE.NUKEM	HN-100 Series 3	190.8	73.2	71.6	3.5	53,000
RWE.NUKEM	HN-100 Series 3 (1” insert)	190.8	75.5	73.6	2.8	53,000
RWE.NUKEM	HN-190-1	193.7	75.6	74.5	2.6	50,000
RWE.NUKEM	HN-194 S	196.3	75.6	75.5	2.1	43,000
RWE.NUKEM	HN-194 (w/insert)	199.1	73.8	80.3	3.5	53,000
RWE.NUKEM	14-215 (1” insert)	217.7	74.3	79	3.5	58,400
RWE.NUKEM	14-215 (1.25” insert)	217.7	73.8	79	3.7	58,400
RWE.NUKEM	TCT (strong-tight)	420	2 @ 76.5	80	0.7	44,000
RWE.NUKEM [(1)]	50-4.0 OL	56.1	48.5	52.5	4.0	28,900
RWE.NUKEM [(1)]	50-3.0 OL	56.1	48.5	52.5	3.0	22,000
RWE.NUKEM [(1)]	50-1.5 OL	56.1	48.5	52.5	1.5	13,200
RWE.NUKEM [(1)]	6-100 L	104.9	61.0	62.0	3.3	42,900
RWE.NUKEM [(1)]	6-100 H	104.9	61.0	62.0	4.4	53,900
RWE.NUKEM [(1)]	7-100	105.7	75.5	40.7	3.5	48,900

(1) Designs exist for this cask, but none have ever been built. In this case, “commercially available” means that they can be built for sale.

Table 5-7
Commercially Available Type B Shipping Casks

Supplier	Container Designation	Internal Volume (ft3)	Internal Diameter (Inches)	Internal Height (inches)	Lead Equivalent Shielding (inches)	Loaded Cask Weight Limit (pounds)
DURATEK	CNS 1-13G	17.0	26.5	54.0	6.2	25,500
DURATEK	CNS-13C	17.0	26.5	54.0	5.7	21,200
DURATEK	CNS 3-55	60.0	36.0	111.1	7.0	56,912
DURATEK	CNS 8-120 B	130.0	62.0	75.0	4.5	49,300
DURATEK	CNS 10-160B	161.0	68.0	77.0	3.1	47,000
RWE.NUKEM	10-142 B with 16" inner lid	140.4	65.5	72.0	4.4	68,000
RWE.NUKEM	10-142 B with 29" inner lid	142.5	66.0	72.0	4.4	68,000
RWE.NUKEM	3-82 B	82.3	54.0	62.1	4.6	50,000
RWE.NUKEM [(1)]	NUC-10-135	142.0	66.0	72.0	4.5	64,000
RWE.NUKEM	PAS-1B	3.5	19.0	21.3	5.1	12,800
RWE.NUKEM [(2)]	10-140	144.5	66.0	73.0	3.6	56,400

(1) Application for approval of the NUC-10-135 is on hold with no projected completion date. In this case, “commercially available” means that the application can be reactivated.

(2) Designs exist for this cask, but none have ever been built. In this case, “commercially available” means that they can be built for sale.

Over the past fifteen years, ownership of waste container designs and container providers has changed hands several times, resulting in two primary providers as of June 2003. Figure 5-1 shows the progression of ownership from 1988 (top) to 2003 (bottom).

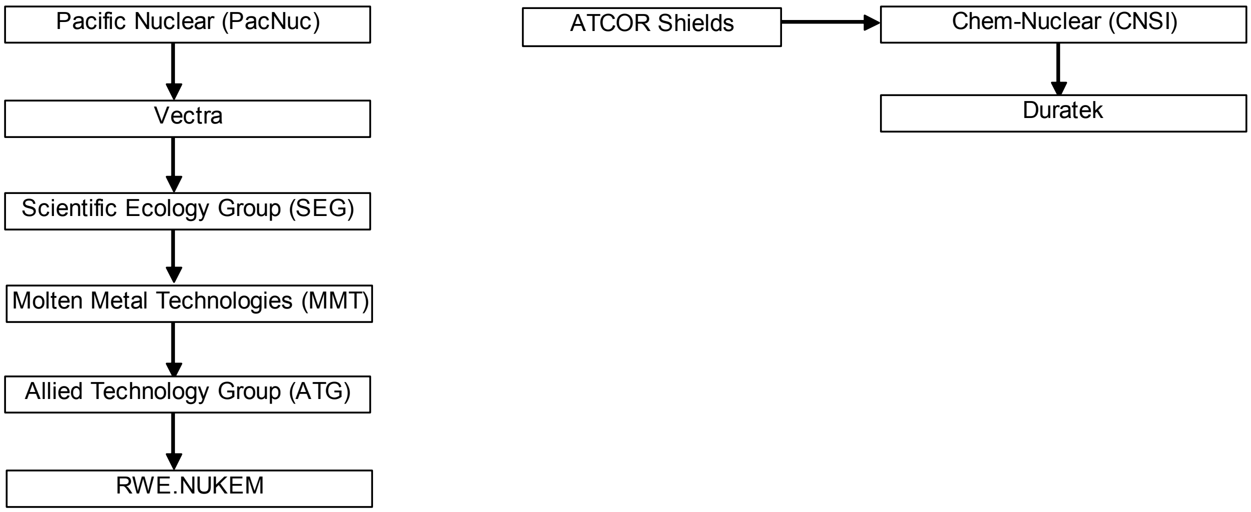

Figure 5-1
Success Ownership of Waste Container Designs and Providers

Container data is subject to revision due to deletions, additions, and modifications of container internals where applicable. For this reason, EPRI has included a set of the most recent container tables as part of the Waste Logic Multi-Site Manager computer software (found in the HELP menu). Revisions to container tables will be included with each new version of the software.

6
ADVANCED CONTAINER TECHNOLOGY APPLICABLE TO INTERIM STORAGE

In addition to information discussed in previous sections, and based solely on existing technologies, waste container selection should also consider the following information.

1. New or emerging container technologies;

2. Commercially available products used in other applications; and

3. Future engineered disposal facilities.

Use of engineered waste disposal facilities creates an environment for the container which is considerably different than for shallow-land burial on which most of the current requirements are based. This section introduces some of these new technologies.

6.1 Impact of Engineered Storage/Disposal on Container Use

United States compacts have generally favored "above-ground" engineered disposal rather than shallow-land disposal based on siting characteristics and siting geology. Texas is a notable exception in that its site geology adequately supports shallow land disposal. In engineered facilities, the structural requirements for waste containers should be different from those for burial. The containers would not have to bear the load of the soil overburden nor the weight of stacked containers if load-bearing spacers are used.

For those facilities in which the waste containers would be cast as a concrete monolith, the concrete would bear its own load. Structural demands on the HDPE and fiberglass HICs in particular should be less stringent. Compacts placing waste containers in concrete silos or overpacks should not require the same degree of waste stability as the others. However, decisions on these issues will be made in the future, and utilities faced with on-site storage and uncertain disposal criteria should probably assume current container structural requirements. For sites that will require solidification of all Class B and C materials, 10CFR61 would not require the use of HICs for these wastes.

6.2 Alternate Container Materials

A full range of sizes for fiberglass HICs was produced in the late 1980’s and early 1990’s. However, as a result of various company mergers and restructuring, fiberglass HICs are no longer available in the US. Similarly, Molten Metal, Inc., obtained approval from the South

Carolina DHEC for a metal HIC for ingots from the catalytic extraction (Q-CEP) process; however, Q-CEP is no longer available. In addition, a 1988 survey of container vendors (Reference 32) found no other new materials being considered seriously for HICs. Foreign reactors, primarily those in Europe, make extensive use of reinforced and impregnated concrete for container material. These are typically lined with epoxy resin paints or butyl rubber (Reference 32).

Based on NRC comments in acceptance of the concrete HIC (Reference 26), suitably sealed and coated concrete should be an acceptable disposal container. Concrete can be reinforced with metal or fibers and can be impregnated with polymers to substantially inhibit liquid penetration into the concrete. In addition, a concrete container design from France was approved by South Carolina DHEC for storage, transport and disposal.

German reactors have made use of cast-iron containers, 15-35 ft^3 in volume, for dewatered evaporator concentrates and resins. Cast iron, coated with suitable protective coatings, should also meet the long-term structural requirements of waste disposal. Practices by U.S. utilities have used limited numbers of concrete containers and have not attempted cast-iron containers.

6.3 Materials for Container Coatings and Lining

A multitude of coating products are commercially available, and specific coating products are often proprietary. The following sections provide some basic and generic information on coating materials and provide some bases for evaluating coatings for application to containers for low level wastes. The data are summaries of several sources from the coatings industry (References 33-38). Specific products, even of the same generic material (e.g., amine-cured epoxy resin paints) can exhibit different properties. Hence, the generic properties are "average" or typical properties. The description of each generic type contains a list of some manufacturers from whom more specific information can be obtained on particular coating products. The Appendix to this report lists the standards to which coating testing is done. A utility desiring to specify a particular coating for a container should request the certification data or results from the coating vendor.

Coatings are applied both internally and externally to metallic waste containers to protect against corrosion damage from the waste and waste products and from the external environment. The coatings presently in use, as well as some others which have recently become available, offer probable solutions to assuring container integrity in packaging radioactive waste for long-term storage and disposal. Coatings function in one of three ways to inhibit corrosion of steel containers (Reference 32).

1. inhibitive coatings - These release ionic material from the pigments in the coatings (often chromates or molybdates) into any penetrating water, thereby curtailing the corrosion process;

2. sacrificial coatings - These contain pigments, such as zinc, and produce a bi-metal electrical corrosive cell in which the zinc becomes the slowly dissolving, sacrificial anode and the steel becomes the protected cathode; and

3. barrier coatings - These have much lower pigment loadings and provide a tighter cohesive film with low permeability to water, oxygen, and ionic material.

Protective coatings for low level waste containers are exclusively the barrier type. This is also true for linings used in some containers. Barrier coatings provide a film that prevents corrosives from reaching the steel surface (assuming application produces a blemish-free layer over the entire surface, including all crevices such as weld points or seams). Barrier coatings used for commercial containers consist of alkyd primer, enamel, melamine-alkyd resin, and epoxy resin paints. Available lining materials are reinforced and impregnated concrete, and polyethylene. Other materials appropriate for providing barrier protection to containers are coal-tar mastics and coal-tar epoxies (Reference 33). Spray or brush painting is the usual application of these coatings that require thicknesses of at least 0.005 inches applied to a freshly sand-blasted metal surface (Reference 34).

Better protection (i.e., pinhole-free layers) results from the application of four light coats than from 1 or 2 heavier coats. Coatings exposed to organic solvents should not dissolve in the solvent. The plastics industry defines solubilities in terms of a solubility parameter factor, called the Hildebrand Factor (Reference 35). The factor is related to the polarity of the solvents and is a measure of the intermolecular forces between molecules, (i.e. cohesive energy density). The Hildebrand parameter has units of $(\text{calories/cc})^{1/2}$. Coatings subjected to organic solvents must have a solubilities parameter values, in units of Hildebrand solubility parameter (H), that are different by 3.2H from those of the solvent (Reference 35). Most aliphatic and aromatic hydrocarbons (common solvents) have factors in the 7 to 9 range. Coatings of typical polyurethane, epoxy, and polyethylene have values of about 10.0, 10.9, and 12.0, respectively. Cured coatings will dissolve in solvents with solubility parameter values within 1.8H of the solvent (Reference 35).

There are many manufacturers that can be contacted for more information on the many coating products. It is suggested that the reader begin by contacting local coating suppliers and paint manufacturers. As an alternative, container manufacturers can usually recommend a local coating supplier.

6.3.1 Auto-Oxidative Cross-Linked Resins

This class of barrier coatings will dry, and ultimately cross link, by reaction with oxygen. All such coatings contain drying oils which form films through oxidative drying. Some metallic salts can accelerate the drying, which occurs at a relatively fast rate after application and then continues at a much slower rate throughout the life of the coating. In resin coatings, the oil (usually vegetable oil) is combined with the resin to add toughness and chemical resistance, thereby improving weather and moisture resistance.

The amount of oil added to the resin affects the characteristics of the product: adding more oil (long-oil modification) gives less chemical resistance and longer drying times but higher penetrability of the coating and better protection to uncleaned surfaces (Reference 33). Adding only a little oil (short-oil modification) makes a material which dries quickly, but it must be applied to very clean surfaces and be cured at about 90°C for a few minutes. Short-oil modification resins have good chemical and moisture resistance but are relatively hard and brittle. Medium-oil modifications are a compromise. The alkyd resin coatings should provide good protection to waste container exteriors exposed to dry but high humidity environments and to most DAW container interiors.

Alkyd Resins

Alkyd resins are the result of reactions from polyhydric alcohols and polybasic acids. The properties result from the drying oil used in the resin. Soybean oil (good drying and color retention), linseed oil (faster drying but color darkening), and castor or coconut oils (good color retention) are commonly used. Alkyd coatings have limited chemical and moisture resistance and relatively low alkali resistance. However, their low cost, easy mixing and application, and superior penetration and adhesion properties make them a popular choice for steel exposed to non-chemical atmospheric environments. Typical applications are:

- in chemical plants away from the chemical processes;
- for bridges and ship superstructures away from the water line;
- for containers, appliances and machinery housings exposed to humid environments.

Modified Alkyd Resins

Alkyds are amenable to modifications (additions) with a number of different resins to improve drying time, color retention, and moisture and chemical resistance. Adding phenolic resin improves retention of surface gloss and enhances water and chemical resistance. Alkyd resins with vinyl modification produce primer paints that can be overpainted with almost any other coating. Silicone modification produces common marine coatings that have enhanced weathering, gloss and heat resistance properties. Alkyds modified with melamine-formaldehyde produce coatings with good solvent (except for strong acids and alkalis) and water resistance properties. The melamine-alkyds have the highest surface hardness of plastic coating materials and are used extensively for vehicles and household appliances (Reference 36).

6.3.2 Thermoplastic Resins

Thermoplastic resins have the characteristic of softening at elevated temperatures. The molecular structure is not cross-linked into a rigid molecule as are either the auto-oxidized or the thermosetting resins. Application is by spraying or painting followed by evaporation of the solvent. The most useful thermoplastics for corrosion control are vinyl, chlorinated rubber, thermoplastic acrylic, and the bituminous resins, asphalt, and coal tar. They have superior resistance to moisture, acids, and alkalis and excellent weathering properties. They will, however, redissolve in their original solvent, and are not normally used for high concentrations of organic liquids. Thermoplastics can provide good waste container protection against inorganic liquids that could exist in small amounts, and its flexibility provides some puncture protection to container walls. Each of the major thermoplastic resins is discussed in detail in the following paragraphs.

Vinyls

Resins Vinyl coatings are from a solution of polyvinyl chloride-polyvinyl acetate copolymer. The solvents are usually ketones or glycol ethers. Most vinyls include a UV scattering material, such as rutile (titanium dioxide), to enhance the UV resistance. Vinyl coatings have excellent water and moisture resistant properties.

Chlorinated Rubber

Chlorinated-rubber coatings are more common in Europe than in the U.S. They are non-flammable and have excellent resistance to acid, alkali, and oxidizing agents. They also have very low water vapor transmission rates (1/10 that of alkyd resins).

Acrylics

Acrylic resins for protective coatings consist of polymers and copolymers of the esters of methacrylic and acrylic acid. The resulting resins, with suitable pigments, have excellent light-fastness, UV stability, and chemical and moisture resistance to weathering. However, they are not recommended for immersion conditions or strong chemical environments because of attacks on the ester groups.

Bitumens

The two bitumens used as emulsions for coatings are asphalt and coal tar. These are distinctly different materials, physically and chemically, and mixtures of the two are not generally compatible. Soaps or colloidal clays are used as surfactants in the production of these emulsions. When highly filled with the surfactants, these lacquers are called mastics. When resins are added to bituminous lacquers, the product is a varnish. The bitumen solvents are normally aliphatic and aromatic hydrocarbons. These can be added sufficiently that the material can be sprayed or painted, or the bitumen can be applied by hot-melt processes. Asphalt has better atmospheric weathering and UV resistant properties than coal car, but coal tar has better moisture, acid and alkali resistance.

6.3.3 Cross-Linked Thermosetting Resins

This class of material refers to coatings whose final properties result from chemical reactions with a copolymer or moisture. Materials in the chemical-reaction group include epoxies, unsaturated polyesters, urethanes, high-temperature curing silicones, and phenolics. Those in the moisture class include polyurethanes and the zinc-laden inorganics. Coatings and linings in the first group give excellent resistance to acids, alkalis, and moisture. They also resist abrasion and ultraviolet and thermal degradation. Chemical cross linking creates large 3-dimensional molecular structures that provide a tough, flexible and highly chemical-resistant barrier to the substrate metal. Epoxy resin paints, particularly those with coal-tar additives, would provide the most protection to waste containers against inorganic and organic liquids. Its hardness provides good abrasion protection, but it also makes it more susceptible to impact cracking.

Epoxy Resin

Common epoxy resins derive from bisphenol A and epichlorohydrin. A curing agent (typically an amine, amine adduct, or polyamide) is mixed before application to start the chemical reaction. When mixed, the components react to yield the cross-linked polymer.

Coal-Tar Epoxies

Coal-tar epoxies are combinations of coal tar and epoxy resins, packaged together, and cured with the normal curing agents. The coal tar acts as a filler with the cross-linked epoxy matrix, giving this coating the toughness, adhesion, hydrocarbon and ultraviolet resistance, and thermal stability of the epoxy, along with the extremely high moisture, acid, and alkali resistance of coal tar. Amine-cured coal-tar epoxies generally have greater chemical and moisture resistance, but are more brittle and harder to apply than others.

Urethane

Urethane coatings have chemical and moisture resistance properties similar to the epoxies. Formulation is from isocyanate-containing material co-reacting with a polyhydroxilated material. Polyurethane, formed from a mixture of epoxies with the isocyanate, gives good chemical resistance, toughness, flexibility and light-fastness. Coal tar can also be added to urethanes to enhance the chemical and moisture resistance.

Summary

Thirty-three test procedures have been established by the American Society for Testing Materials (ASTM) and the National Association of Corrosion Engineers (NACE) for evaluating coating and lining materials (Reference 38). These are listed in the Appendix to this report. Table 6-1 summarizes the properties of the plastic materials suitable as coatings for low level waste containers. The Table presents relative values that originate with uses of the material as recommended by the manufacturer (Reference 37) and by tests and evaluations (References 34 and 38).

Of the listed coating materials, the alkyd paints are more suited for exterior coatings, and the epoxies, particularly the coal-tar additive epoxies, are better for interiors of containers containing dewatered resins. All the coating materials are available as commercial products, and more specific information is available from the suppliers of each product. Table 6-1 also lists relative properties of radiation resistance, film toughness, surface hardness, and abrasion resistance. These are qualities important to specific applications, and their importance should be considered relative to those applications. Since the organic- based materials are solids when they become coatings, they should not constitute hazardous or toxic materials.

TABLE 6-1 COLUMN DESCRIPTION KEY:

COLUMN DESCRIPTION

Mild to moderate atmospheric water vapor and chemicals
Heavy industrial atmospheric water vapor and chemicals
Marine atmospheric environment
Resistance to moisture and chemical vapor penetration
Sea water immersion or intermittent immersion
Alkali immersion or intermittent immersion
Strong acid immersion or intermittent immersion
Hydrocarbon immersion or intermittent immersion
Burial Gamma- and beta-ray radiation resistance
Surface hardness Film toughness Abrasion resistance
Penetrability of coating into surface.

Table 6-1
Relative Properties Of Auto-oxidation Crossed-Linked Resins

Coating Material	Mild Water Vapor	Heavy Water Vapor	Marine Environment	Water Resistance	Sea Water Immersion	Alkali Immersion	Acid Immersion	Hydrocarbon Immersion	Burial	Radiation Resistance	Surface Hardness	Film Toughness	Abrasion Resistance	Penetrability
Solvent-based Alkyls														
Long-Oils	R	R	R	A	N	N	N	N	N	A	A	A	A	R
Medium-Oils	R	R	R	A	N	N	N	N	N	A	A	A	A	A
Short-Oils	R	R	R	A	N	A	A	N	N	A	A	A	A	A
Modified Alkyls														
Melamine Formaldehyde	R	R	R	R	A	N	N	R	N	A	R	A	N	A
Silicon	R	R	R	R	N	N	N	A	N	A	A	A	A	R
Thermoplastic Resins														
Vinyl	R	R	R	R	R	R	R	R	R	A	N	A	A	A
Chlorinated Rubber	R	R	R	R	R	R	R	N	R	A	N	A	N	A
Acrylic	R	R	R	R	N	N	N	N	N	A	N	A	N	R

Coal-Tar Bitumen														
Solvent cutback	R	R	R	R	R	R	R	N	R	A	N	A	N	A
Hot Melt	R	R	R	R	R	R	R	N	R	A	N	A	N	R

Response Key

R = Manufacturer recommended for the application (highest ranking).
A = Acceptable for the application (medium ranking).
N = Not recommended for the application (lowest ranking).

Table 6-2
Properties Of Cross-Linked Thermosetting Resins

Coating Material	Mild Water Vapor	Heavy Water Vapor	Marine Environment	Water Resistance	Sea Water Immersion	Alkali Immersion	Acid Immersion	Hydrocarbon Immersion	Burial	Radiation Resistance	Surface Hardness	Film Toughness	Abrasion Resistance	Penetrability
Epoxy														
Amine cure	R	R	R	R	R	R	R	R	R	R	A	R	R	A
Amine Adduct Cure	R	R	R	R	R	R	R	R	R	R	A	R	R	A
Polyamide Cure	R	R	R	R	R	R	R	R	R	R	A	R	R	A
Other														
Coal-Tar Epoxy	R	R	R	R	R	R	R	R	R	R	R	R	R	A
Urethane	R	R	R	R	R	R	R	R	R	R	A	R	R	A

Response Key:

R = Manufacturer recommended for the application (highest ranking).
A = Acceptable for the application (medium ranking).
N = Not recommended for the application (lowest ranking).

6.3.4 Applying Coatings

A clean and properly prepared surface is important to achieve a blemish-free coat adhering uniformly over the entire container surface, including crevices. The surface should be free of oils or any other substance that could flake from the surface or otherwise cause areas of non-adhesion, particularly in seams and comers. A freshly sand-blasted surface provides the best surface adhesion for the coating layer.

Container application is usually by wet brush or spray or through sprayed powders. Industrial applications obtain the most uniform coatings through wet or powdered spraying. Most pin-hole free layers result from several applications of thin layers (about 4) to a total thickness of at least 0.005 inches.

6.3.5 Currently Used Container Coatings

Melamine-alkyd resin and epoxy-resin paints are used as coatings on some steel containers as corrosion inhibitors. Japanese studies using the melamine-alkyd paint on the outside of 17H containers and epoxy paint on the inside gave projected lives of 80 years when immersed continuously in either river or sea water (Reference 33). Interim storage or a disposal facility would be a considerably less harsh environment than continuous immersion.

Some U.S. waste container suppliers coat the inner and outer surfaces of waste containers with epoxy, alkyd enamel or primer paints. Linings of polyethylene or concrete are available on some steel liners, on- site storage containers, and HICs. Other coatings, either singly or in combination, could provide improved integrity to low level waste containers. One vendor estimated that applying sprayed-on coatings of thermoplastic coal tar to DAW drums or boxes would increase the container costs by about 20% (Reference 39).

An additional product consists of a combination a vinyl thermoplastic and a polyamide thermosetting resin. Both are proprietary and are proposed for coating steel containers (References 26 and 40). The thermoplastic material provides the protection from chemical corrosion, the thermosetting material provides protection against ultraviolet radiation, and the steel provides the mechanical strength and rigidity. An infused additive also allows the coating to actively destroy many forms of bacteria, fungi and viruses. The application technique is the crux of the process and is reported to result in a two-part film over all surfaces and crevices of the container that is 0.009 inches thick. The layer is applied as an electrostatically sprayed powder that is set by baking. Test results of the coating indicate excellent performance in all the tests and fulfills the acceptance criteria presented in Section 3 of this report, including impact and abrasion resistance. The coating could provide a practical mechanism to upgrade carbon steel boxes and liners for any waste. NRC approval of the process would allow coated carbon steel containers to be considered as HICs.

7 CONTAINER SELECTION CONSIDERATIONS

In selecting containers for interim storage of low level wastes, particularly when the desire is to ship the stored waste without reprocessing or repackaging, utilities should consider a number of issues. Of primary concern to this report are:

1. the practicality of handling and storing the packaged waste,
2. maintaining the integrity of the container during storage,
3. verification prior to disposal that there are no free-standing liquids, and
4. acceptability of the waste package both for transport and disposal at the time of shipment.

Reference 37 discusses several of these issues, particularly regarding the connection between container selection and storage facility design. As these issues are well known, this section includes them for emphasis and as a matter of being comprehensive.

7.1 NRC Container Approvals and Construction Material Considerations

The only containers considered for approval by the NRC are high integrity containers (HICs). However, NRC approval of a container or design is not necessarily a requirement for Class B and C waste acceptance at a disposal site. For example, Barnwell and Hanford accept polyethylene HICs that are not pre-approved by the NRC, but only when they are enclosed and buried within a concrete overpack. Nonetheless, there is a relatively high probability that the new compact sites will rely heavily on NRC recommendations in the existing disposal acceptance criteria. Presently approved HIC designs are:

1. a fiber-reinforced concrete container produced in Japan;
2. a concrete container produced in France;
3. a high-chromium content stainless-steel container, developed in Great Britain and licensed in the U.S.; and
4. a molded polyethylene-lined stainless-steel container.

7.1.1 High Density Polyethylene (HDPE) Containers

The issues with HDPE are the potential for embrittlement, stress- and radiation-induced cracking, and material creep buckling that would exacerbate the failures. Primary short-term failures of HDPE are ductile, whereas material creep buckling causes deformation resulting in cracking. Long-term failures result from embrittlement where the material fails without extensive deformation. Both of these failure modes would apply to polyethylene. Radiation decreases the tensile strength of HDPE, up to a total dose probably in excess of 10^8 Rad. It also increases the brittleness. Even without radiation effects, HDPE becomes more brittle with time for reasons that are not fully understood (References 42-43).

Two investigators studied the mechanical stress limitations and reported on the ability of HDPE to withstand a trench disposal environment (References 42-43). Both studies concluded that HDPE HICs would likely fail in less than 300 years in shallow-land disposal sites, but pointed out that uncertainties in the available data make such predictions difficult. One of the reports concluded that wall thicknesses up to two inches were required to prevent buckling and the onset of the cracking.

The NRC and the existing burial sites give no credit for mechanical support from container contents to prevent buckling, and the containers must survive on their own. Brookhaven National Laboratory has studied the mechanical properties of polyethylene, and their related report (Reference 44) suggests synergism between stress, time, integrated radiation dose, dose rate, and corrosive chemical byproducts. The Empire State Electric Energy Research Company (ESEERCO) contracted with Brookhaven to generate more test data to resolve some of these issues (Reference 21). Because of the complexity of the issues, resolution may not be possible in any reasonable time, and, in the near term, any resolution is not likely to convince the NRC to approve HDPE HICs.

7.1.2 Container Corrosion

Another study supported by the NRC and conducted by Brookhaven National Laboratory (References 46-49) discussed issues and concerns of extended on-site storage of low level radioactive wastes. This study focused on deterioration of the waste form and the waste container during storage. Only carbon-steel and polyethylene containers were considered in the research, and the conclusions regarding high-density polyethylene are those discussed in Section 7.1.1.

For carbon-steel containers, the study considered the potential for damage and failure from both internal and external corrosion. Corrosion mechanisms of concern are:

1. uniform attack of the entire container,
2. localized attack (pitting and crevice corrosion),
3. galvanic action,
4. de-alloying attack (dissolving of one or more components of an alloy), and

5. stress-corrosion cracking.

Brookhaven analyzed data on steel drums and liners from TMI-2, INEEL and Hanford, and from tests of materials performed at Brookhaven to develop corrosion rates from exposure to various substances. The corrosive environments included moisture, acids and caustics, resins, and products resulting from radiation degradation and biodegradation of resins, filters, sludge, and various solidification media. Their principal conclusions were:

1. Corrosion by the atmosphere, generally in the form of uniform corrosion, results from the interaction of carbon steel container material with the atmosphere and depends upon the temperature and the relative humidity. This is the familiar, if somewhat difficult to qualify, type of corrosion known as “rust.” Rates of 0. 1 to 0.5 mils per year are reported for the atmospheric corrosion of steels in an industrial environment; these values are ten-year averages with about half of the corrosion occurring during the first year.

2. Corrosion rates of 0. 4 to 5 mil/year have been reported for mild steel immersed in various simulated unsolidified LLW (This is of relevance for carbon steel containers with Class A waste, which does not have to be solidified but only dewatered).

3. Corrosion of carbon steel embedded in solidified wastes has also been observed. It is minimal for steel embedded in cement. Corrosion of metals in bitumen has been attributed to biodegradation. A corrosion rate of about 0.01 mil per day is reported for mild steel embedded in waste forms consisting of a chelating decontamination reagent sowed in vinyl ester-styrene.

The study found that corrosion, both internal and external, concentrated in regions where there were pits or crevices, such as joints and scams. Some coated containers were studied wherein the film had been applied to uncleaned and blemished surfaces. Areas of coating separation or blistering were severely corroded. This finding reinforces the need for a paint or other barrier coating to be applied to containers to inhibit corrosion. The coating must be a continuous film over a prepared surface, including the scams and joints.

7.2 Container Acceptance for Disposal

In order to minimize the risk of having to repackage waste at the time of shipment, the probability of container acceptance by the disposal site must influence the container selection process. These considerations should include DAW containers, steel liners, and HICs.

Steel liners have not been tested to meet the IP-2 qualification criteria in 49CFR173 nor those of 10CFR71.71 but could continue to be shipped in casks. There is no indication that there is any problem with their acceptance at disposal sites for solidified or Class A wastes. However, utilities should seriously consider coating these containers for longer-term integrity.

If HICs are necessary or desired, utilities should carefully consider regulatory acceptance of the HICs and their contents. Polyethylene HICs will probably not be approved by the NRC, although they are accepted by current disposal sites provided they are placed in overpacks (engineered concrete barriers). The status of some other materials and linings is unsettled, and acceptance of fiberglass HICs or thermosetting or thermoplastic linings may not be known for several years.

7.2.1 Combining Waste Streams in Containers

A common practice is disposing of filter cartridges and dewatered resins as a single waste. NRC waste classification rules permit this practice if classification is determined for each waste stream and the higher class governs the package. The practice presents difficulties if a mixture needed to be repackaged, and worse yet if both components had deteriorated. Utilities should be aware of this possibility in selecting containers and packaging techniques for filter cartridges. Steam reforming of resin and filters produces a new, homogeneous waste form. This offers a potential solution for some wet solid waste.

7.3 Maintaining Container Integrity During Interim Storage

Container acceptance by the NRC, DOT and compact authorities is perhaps the most important criteria for LLW container selection. This is especially true for storage situations, as regulatory and compact acceptance will substantially reduce the expense and radiation exposure associated with repackaging for disposal. However, there are many other important factors which must be considered in selecting the appropriate containers for on-site storage. The more significant items are:

1. Container seals and vents
2. On-site storage and handling
3. Container shielding
4. Container coatings and linings

The common thread which connects these items is the objective of maintaining container integrity during the storage period. Hence, each of these is discussed as a separate subsection below.

7.3.1 Container Seals and Vents

If the utility's particular compact site is uncertain about the waste form requirements, or if the utility prefers for other reasons to store higher level wastes in a form requiring further processing before shipment, the utility should consider as part of the container selection process the requirement to re-open the container after storage. Seals or gaskets that become bonded through corrosion, long-term pressure, or chemical deterioration, would create problems in re-opening the container.

The container vent is commonly a 3/4-inch carbon-carbon insert into a stainless-steel sleeve. The vent is an absolute particle filter that has an efficiency of 99.98% for particles of 0.3-microns in diameter. Particles of this size are the most difficult to filter, and the filtration efficiency is greater for both smaller and larger diameter particles. The flow specifications of the filter require a minimum gas flow of 200 cc/min at a pressure differential of 1.0 inch of water.

The container vent should not plug under normal dust-loading conditions in the container thermal breathing cycle (Reference 50). However, in very dusty environments for long-term storage, plugging could occur. The vent also can saturate and plug from water if left exposed to the weather. The utility should consider potential water and dust loading of the vent in facility design and operation.

7.3.2 On-Site Storage and Handling

Conditions in each specific storage facility will influence the requirements on containers for storage and disposal. These influences are detailed in Volume 2 of the EPRI Interim On-site Storage of LLW report series (Reference 1). Utilities should account for these aspects in the container selection process.

Controlling Container Corrosion and Damage

In selecting containers, utilities should consider practicalities that would reduce the probability of container breach during packaging, handling, and storage of the wastes. This includes not only the effects of internal and external chemical corrosion but also possible damage during handling and storage, such as impacts or puncture from handling equipment, dropping, and abrasion from other containers or casks. Most radwaste managers have experience with 'old' containers that have disintegrated or been ruptured during handling and recognize the benefits of preventing recurrence.

When stored in dry areas and climates, the 1A2 drums used to hold some defense DAW have, for the most part, retained their integrity for up to fifteen years (Reference 51). However, they show considerable external rust. The condition of the internal surfaces is unknown. Even storage of dry, but vented, containers for several years can cause internal corrosion from water introduced through container “breathing” during temperature cycling. This can generate considerable moisture during the years of storage in moist climates.

Rusting of DAW containers and some containers holding moist wastes can be controlled through the selection of adequate container materials, coatings and lining applications. Utilities should consider using high-quality coatings for steel containers. Protection against mechanical breaching can be enhanced through adequate facility and handling equipment design and usage, through careful selection of containers, and through protective coatings.

Utilities may elect to store the higher activity Class B and C containers in on-site storage modules. It is likely that these modules will afford greater protection from damage except during loading operations.

In the selection process, utilities must consider the long-term integrity of the container grapple rings, lifting lugs, and slings along with the rest of the container.

Storage Facility Arrangement

Stacking of loaded waste containers, particularly of the larger containers, can require additional container mechanical strength or rigidity. Drums or boxes of low-density DAW have been stacked in warehouses as much as five high with no difficulty (Reference 51). Liners can usually be stacked two high, whereas polyethylene or fiberglass HICs would require spacers for stacking or “stackable, grappable” support structure. The actual height to which containers can be stacked depends upon the gross weight of each and the manufacturer specifications.

Other factors, such as required shielding and accessibility, should also be considered in selecting container size requirements. Accessibility is a requirement for inspection and monitoring of container integrity. Those issues are discussed in a separate document (Reference 52). The utility may elect to use on-site storage modules for storing some Class B or C wastes and available sizes would limit container selection. Shipping cask shielding requirements will continue to influence container size selection. Because of the relatively short half-life (5.3 years) of the usually dominating ^{60}Co nuclides, the cask type needed could change during storage, thereby allowing some additional container choices.

Storage Facility Waste Handling Capabilities

An additional consideration can be the height and configuration of the container lifting sling. Sling heights, vary among the commercially available containers. Other individual site factors also may influence container design needs, such as the need for grappling rings or pallets for use with fork lifts. It will likely be necessary for most on-site storage facilities to possess overhead cranes for handling the present generation of liners, HICs and casks. It will also be necessary to manipulate DAW containers either by crane or fork lift and using pallets or grapples.

7.3.3 Container Shielding

In selecting containers for Class B and C wastes particularly, the utility should consider the final activity and radiation levels of the packaged waste in terms of requirements for Type B shipping containers and for radiation shielding. Containers requiring a Type B cask for shipping are currently limited to container volumes less than about 158 ft^3. Shielding resulting from solidification, and reduction of the activity of the usually dominant ^{60}Co through decay in extended storage, could reduce the requirement for a Type B package. Encapsulation of filters also reduces container dose rate and may eliminate the need for a Type B cask.

The subject of shielding is covered in Volume 2 of the EPRI Interim On-site Storage of LLW report series (Reference 1). For radiation shielding during storage, a utility may wish to use on-site storage modules, shielding walls, or compacted Class A waste (Reference 1). Space requirements and the choice of shielding design may influence container selections.

7.3.4 Container Coatings and Linings

Selecting a coating or a lining material for the container is an important aspect in inhibiting corrosion and, thereby, assuring the integrity of steel containers. Since the design and qualification of HICs inherently includes assurance of their integrity, utilities may not need to consider coatings for those containers. Thus, this section of the report limits coating and lining discussions to steel drums, boxes and liners. Manufacturers and suppliers of these containers have stated a willingness to supply any commercially available coatings desired.

Selection of an appropriate coating material involves a number of considerations and decisions by the utility. The primary considerations are:

1. container external exposure conditions;
2. internal corrosive chemicals and substances, concentrations, and radiation;
3. estimated duration of storage or corrosive conditions;
4. requirements for abrasion and puncture resistance;
5. utility restrictions on organic materials; and
6. data on performance and costs of coatings.

External Conditions

External environmental conditions are important. As examples of extremes, containers exposed to severe weathering, corrosive atmospheres, or significant temperature changes will require different coatings than those containers in an environmentally controlled building.

Internal Conditions

Internal corrosion is even more important, since its effects cannot normally be seen until the container is breached. The more important applications are for dewatered resins and filter cartridges where the potential exists for biodegradation or chemical leach products to concentrate in the small amount of liquids present in the waste. Less important, but still significant, are internal coatings for DAW drums and boxes. This is particularly true for overpacks of compacted waste where some local corrosive pockets may exist, and uncompacted waste, where puncture or abrasion have the potential for failing the container.

Storage Times

Estimates of storage periods are important. Longer periods result in greater corrosion control requirements and usually give greater risk of external abrasion and puncture damage from handling operations.

Storage Facility

Storage facility design has important aspects for external container coating requirements. Stacking, storage in on-site containers, and container handling devices all affect the requirements for protection against external abrasion and puncture.

Hazardous Chemical Restrictions

In selecting a container coating, the utility should consider any restrictions on organic compounds that may limit the choices, although there should normally be no restrictions on conventional coating materials. The coating and lining materials discussed and listed in Section 6.3 are common materials. The coatings normally would be applied by the vendor rather than the utility and would thus be as solid plastics having no solvent liquids or vapors.

Coating Performance Specifications

The utility should review the manufacturer recommendations and performance test data before selecting a specific coating. There are sufficient differences in performance between different products of the same generic type of material identified in Section 6.3 that each specific product requires evaluation (Reference 36). The utility is faced with a huge array of specialized products that have been developed and tested by the coating manufacturers. Many of these products are proprietary and data may be difficult to obtain. Nonetheless, a utility should review the test results. Many of the coatings have undergone extensive field testing, whereas others are relatively new and untested.

Coating Application

The application of coatings to containers is at least as important as selection of the coating material. The film should be at least 0.005-inches thick, should cover all surfaces, joints, and crevices, and should contain no pinholes or other blemishes. Any pathway through or around the layer of coating material will result in corrosion and potential failure. External scratches or punctures of the coating should be immediately repaired or the container should be placed in an overpack.

8
LESSONS LEARNED

This Chapter provides the user with some of the lessons learned by utilities with existing on-site LLW storage facilities. The intent is to highlight issues which can enhance storage facility operations or impose operating limitations.

Each item listed stems from a challenge encountered by utilities in developing their LLW storage program or while operating their interim LLW storage facility. Although the exact nature of the challenge is not described in detail, users still have the opportunity to benefit directly from the experience of their peers. These experiences have occurred over a wide range of facility designs and may not all apply to any single design or storage facility.

8.1 Waste Containers and Waste Forms

1 Many plants have experienced a need to reprocess waste following on-site storage due to incomplete or changing disposal facility waste form acceptance criteria. For example, polyethylene HICs were delivered to one plant inside steel overpacks to satisfy fire protection commitments made to allow storage of unprocessed resin. This was done because the plant was reluctant to stabilize the resin by solidification without having a clear waste form acceptance criteria from the local regional LLW compact. Resin was transferred into the HIC while inside the steel liner; the HIC was dewatered to meet the free standing water criteria; the lids were installed on both containers; and the material was placed in interim storage.

The dewatering method was only viable for 90 days based on vendor test reports. Provisions included for each HIC allowed the containers to be dewatered at the end of the storage period without reinstalling the fill head.

When Barnwell reopened to the plant for disposal, the resin containers were removed from storage; both lids were removed (steel overpack and polyethylene HIC); and the dewatering verification tube was attached to verify compliance with free standing water criteria. One liner exceeded the Barnwell disposal criteria for free standing water, whereby the plant concluded that all HICs would require reprocessing prior to shipment to the disposal facility. Consequently, all of the HICs were dewatered again. In addition, the disposal fee structure – which was based on external package disposal volume – provided an economic incentive not to dispose of the overpacks. All of the HICs were extracted from their overpacks, transferred to a shipping cask, and shipped to Barnwell for disposal.

An important lesson learned from this situation is that stored, unsolidified resins should be inspected for free standing liquids prior to shipment for disposal. Another lesson is that uncertainties in post-storage disposal site waste acceptance criteria will commonly result in conservative stored waste forms (e.g., dewatered rather than solidified resin). This is an appropriate response as it preserves the ability to reprocess if waste acceptance criteria change prior to disposal. The long term impact is an increased potential for reinspection requirements and reprocessing, including the increased radiation exposure and cost commitments. This consideration should be factored into the analysis of the optimum waste form for any waste type in storage.

2 Another plant identified a need for an interim storage solution for filters. Existing regional compact waste form guidance indicated a potential requirement for stabilizing the material by performing insitu encapsulation after placing the filters in a cage within a disposal liner or HIC. However, it was decided not to encapsulate the filters for storage because of the potential for having to repackage the material pursuant to likely future changes in regional compact waste acceptance criteria.

There also was a concern about future gas generation from cellulose media on some of the filters. To resolve this dilemma, it was decided to store the filters within an encapsulation cage inside a HIC but without adding a solidification media. The plant also procured a filter cutter/crusher to improve the packaging efficiency for filters.

When Barnwell reopened, the plant reinspected the filter HICs in preparation for disposal. During inspection, it was noted that a significant quantity of liquid had accumulated in the bottom of the HIC as the filters continued to drain while in storage. The filters were grouted with cement. ***This demonstrates the importance of careful reinspection of filter containers prior to shipment for disposal. It also highlights that storing filters in a form suitable for future encapsulation was a prudent action.***

3 LLW storage is not free from uncertainties in terms of final waste form. Several plants have experienced additional moisture accumulation in the form of free standing liquids as a result of thermal cycling, release from resin of insitu liquids (i.e., conversion to water of hydration), or continued draining of filters which had not been encapsulated.

4 Following an extended interim storage period, inspection of compacted waste in steel boxes at one utility found a combination of expansion in some boxes and waste slumping in others. These boxes all used anti-springback devices, which likely accounts for expansion. This was resolved by switching to a heavier-duty box with reinforced (angle iron) closures and bracing. The waste slumping appears to have been caused by a combination of continued release of entrained air and decomposition of some waste materials. All of these experiences reinforce the importance of a good monitoring and inspection program both during interim storage and prior to shipment for final disposal.

5 Inadequate crane clearance forced one plant to use smaller containers for resin storage. The plant decided to store its resin in a building that had been constructed in 1986 and which was originally designed as a palletized drum storage facility. The inadequate crane clearance challenge was resolved by purchasing a unique sized (75 ft^3) HIC.

Note: Inadequate crane clearances, including crane-to-cask and crane-to-liner-to-cask, have been reported by several utilities operating LLW storage facilities.

Careful engineering analysis is needed to avoid this problem. Utilities planning new or modified storage facilities should consider Figure 8-1 in Section 8.2 as part of the evaluation process.

6 Planning for the maximum size of any material loaded into a storage canister will minimize the total number of cuts. This, in turn, will reduce the project duration, the total exposure, the project cost, and the total volume of waste generated and stored. This seemingly minor point is very possibly one of the most important decisions made by a decommissioning nuclear plant, and it applies to all waste removed from the plant (i.e., cut the waste to fit the shipping or storage container).

7 Decommissioning plants commented that the use of ultra-high pressure (UHP) water cutting for high activity materials worked well in terms of matching cut length to container dimensions. Competing experiences also pointed out that vendor experience was a key factor in the success of UHP cutting. If the cutting process is not carefully controlled, significant contamination control problems arise, including discrete radioactive particles. In addition, poor control of the process can result in a substantial increase in total project dose. Prior to using UHP cutting for reactor internals, plants should evaluate the experiences and lessons learned by other plants. (Intentionally duplicated from Section 10.5.)

8 Changes in container selection and sizes should be accompanied by a reevaluation of the storage plan. This is particularly true for vaults designed with specific container dimensions and vertical height restrictions.

9 Changes in storage containers and other stored materials should generate a review of fire protection requirements and capabilities. This is particularly true for facilities storing polyethylene high integrity containers (HIC) and large quantities of wooden pallets.

10 Many plants have reported the need to dewater spent resin again after an extended period of storage prior to disposal. This applies only to resin for which dewatering was the processing method of choice prior to storage.

11 Storage of polyethylene HICs which are to be stacked require that the HICs have either a rigid overpack or a “stackable” support structure. (Note that composite poly/stainless steel HICs cannot be stacked.) Either option commonly requires a grappling configuration to allow for easy lifting. This can increase the cost per HIC by $5000 or more. Also, at the end of the storage period, the rigid overpack or a “stackable” support structure must be decontaminated or managed as LLW (typically by disposing with the rest of the waste package).

12 Steam reforming of spent resin offers a typical volume reduction ratio of 6:1 or better. Vendor experience indicates that not all containers with the same external volume have the same useable internal volume due to wide variations in the types of dewatering internals, including the number and sizes of dewatering filters. Accordingly, some containers result in a high volume of secondary filter waste and lower spent resin capacity with higher overall cost.

8.2 Waste Container Handling

1. The use of remote handling equipment should be evaluated. A high-capacity overhead crane covering the entire facility is one option that could minimize container handling difficulties.

2. The crane should have adequate lift clearance to allow for future use of larger containers and casks, the limit of which can be estimated based on road bridge clearances (14 feet is typical). Vertical lift clearances should consider all of the clearances identified in figure 8-1 below:

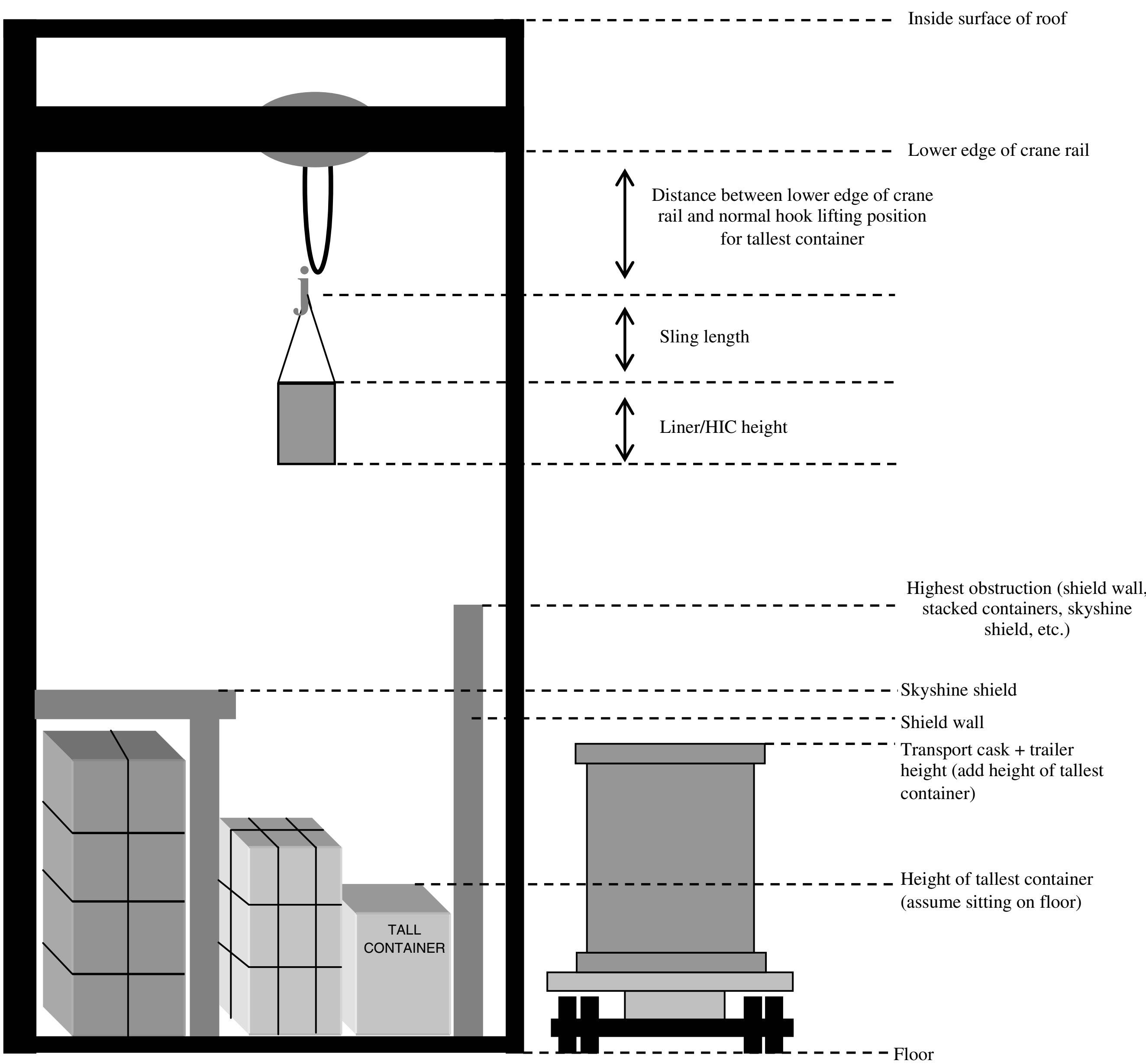

Figure 8-1
Considerations for Determining Vertical Lift Clearances

3. Cranes should have multiple speeds for all movements. (Some cranes are very slow.)

4. Crane lighting should not be obstructed by the largest containers or storage modules being rigged.

5. Lifting capacities for mobile cranes should be based on lifting the heaviest load at the maximum reach of the crane. An appropriate margin for error should be included for crane capacity.

6. If a forklift is used for waste handling, there should be a loading dock or ramp for accessing flatbed trailers and enclosed vans.

7. If a forklift battery charging station is included in the facility design, an eyewash station should be located nearby.

8. Provisions should be made for periodic inspection and certification of crane rigging.

9. Rigging used on high activity packages should be subjected to an ALARA review for dose minimization and extended life. The optimum approach would be to use steel cables or leave steel shackles on the liner/HIC. If the shackle approach is used, store nylon slings in an accessible area and replace as necessary.

10. Most nuclear plants use their LLW storage facilities to accumulate enough waste to fill a shipping vehicle. This practice is referred to as “staging” the waste rather than “storing” the waste. However, nuclear utilities have reduced LLW volumes dramatically over the past several years. As such, annual stored waste volumes and annual waste generation volumes at some nuclear plants amount to considerably less than one shipment of waste. This would indicate that some plants would need five or more years to accumulate enough staged waste to justify a single waste shipment.

    In an effort to minimize stored waste volumes while accumulating enough to make an exclusive use shipment, at least one nuclear plant has switched to brokered shipments (turning waste over to a third party shipper to fill a shipment from multiple waste generators). This is a common practice for many non-nuclear LLW generators, such as hospitals and research facilities, but it is a new concept (and positive opportunity/lesson learned) for nuclear plants. Such shipments are well within the capabilities of nuclear stations, subsequent to some potential procedure modifications.

8.3 End of Storage Considerations

1. Waste settling during storage can create excessive void spaces (frequently >15%) for some waste packages. This applies primarily to nonmetal wastes which were placed in storage without volume reduction processing. This must be identified and, where necessary, the waste should be repackaged.

2. Many plants which experienced one or more periods of interim, extended storage provided feedback on lessons learned at the end of the storage period while preparing to ship waste for disposal. Repackaging was not particularly common, although reprocessing (dewatering) of

previously dewatered resins and filters was common. The following insights were provided from a nuclear plant which experienced an 18-month interim storage period following the closure of Barnwell in 1994/95:

- Five wet waste containers were placed in storage: four with resin; one with filters. At the time, polyethylene HICs were the most common storage approach in the US. Resin solidification was not practical at that time, and there there was no nationally approved binders for filter encapsulation. Moreover, design restrictions inherent to the local storage facility (restrictive sizing of high activity storage vaults) precluded storage in commercially available ferralium HICs.

- The high activity storage vaults are designed for storage of 80 ft^3 containers. Because that is an unusual container size, they are exceptionally expensive.

- The plant fire protection staff required that all polyethylene HICs be placed in metal overpacks (as experienced at other plants, both in the US and internationally), which further increased storage costs per container.

- All resin was dewatered, but the dewatering equipment test report was only valid for 90 days. After that period, the residual water content within the container was no longer certified to meet disposal criteria. This meant the plant would have to verify that no freestanding water was present before shipment for disposal.

- The plant arranged with the HIC supplier to install a separate dewatering verification tube with a stone filter at the bottom of the HIC. A connecting tube could be easily attached to a fitting in the cover plate of the HIC under the plastic lid, allowing for any freestanding water to be removed without the use of a fill head. This was an excellent pre-planning approach which reduced labor time and some of the associated radiation exposures for removing any residual water.

- Of the four resin HICs placed in storage, three exceeded the free water criteria when removed from storage. The entire process of verification and removal of any freestanding water was both labor intensive and dose intensive. Each metal overpack had to be opened, the plastic HIC lid was removed, the dewatering tube was attached, and the HIC dewatered. The polyethylene HICs also were removed from the metal overpacks and shipped separately for disposal to reduce disposal costs. The entire process from storage removal to shipment averaged one week per stored waste container.

- Filters were stored within a HIC with a suspended encapsulation basket. They had not been cement-encapsulated, as no nationally approved cement binder existed at that time. However, since some of the filters contained a cellulose matrix, a potential existed for gas generation. If gas generation had become a problem, the selected container could have been filled with cement to mitigate the problem.

- Upon removal of the filter HIC from storage, water could be heard sloshing in the bottom of the container. It was estimated that several inches of water were present in the container, and it was solidified with cement prior to disposal.

- The quantifiable impact to the plant for removing, dewatering, and preparing these five containers for disposal was an extra $40,000 per container and an extra 420 mrem per container. The plant estimates that all of these costs and the associated dose could have been avoided if the waste had been solidified prior to storage.

- The plant also removed a sixth container which had been in storage for more than two years. This was an empty metal liner. Although the container was indoors with its lid secured in place, approximately one inch of water was found inside the liner. The liner had a passive vent, and the plant believes that moisture entered the liner via the passive vent. Thus, the source of the water was dew formation on the walls of the container. Again, this emphasizes the need for verifying the absence or presence of freestanding water in wet waste packages prior to shipment. It also highlights the potential benefits of solidification prior to storage.

A
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B GLOSSARY

ALARA As low as is reasonably achievable. As low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and other societal and socio-economic considerations, and in relation to the utilization of atomic energy in the public interest. (This definition is from pre-1989 versions of 10CFR20).

backfitting Defined by the NRC as "modification of or addition to systems, structures, components, or design of a facility...or the procedures or organization required to design, construct or operate a facility...which may result from a new or amended provision in the Commission rules or the imposition of a regulatory staff position interpreting the Commission rules that is either new or different from a previously applicable Staff position.

becquerel A measure of radioactivity. The becquerel is the derived unit of radioactivity in the International System of Units (SI), symbolized as Bq, and equal to one disintegration or nuclear transformation per second. There are 37 billion Bq in one curie.

BWR Boiling water reactor.

by-product A secondary waste or material from decontamination or other process.

byproduct material According to10CFR20.3 byproduct material is "any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or Utilizing special nuclear material." That is, all radioactive material in the plant except part of the fuel.

cf Cubic feet. Also, abbreviated ft^3.

CFR Code of Federal Regulations.

characterize Usually, to determine radiological characteristics, including chemical and physical characteristics (chemical form and/or particle size).

Ci Abbreviation for curies, a measurement of activity .

Compact See Low Level Waste Disposal Compact.

contamination Contamination means material where it is not wanted. Usually used to mean radioactive contamination; radioactive material where it is not wanted.

conversion reforming Steam reforming accomplished in a tank conversion reformer. (See steam reforming.)

curie One curie equals 3.700 X 10E+10. That amount of radioactive material which disintegrates at the rate of 37 billion atoms per second.

de facto onsite disposal Radioactive waste which is stored indefinitely with no alternative for disposal. Hence, the storage facility itself becomes a de facto storage facility.

design basis event The maximum credible event (hurricane, earthquake, core damage, etc.) which could occur at a facility. Such an event forms the basis for the plant design so as to ensure the protection of public health and safety .

design capacity The maximum quantity of radioactive material which can actually be stored in an interim storage facility in accordance with its overall design. This takes into consideration both the interior storage volume *and* the maximum levels of radioactivity generated by the number of curies which can be stored.

disposal allocation The amount of radwaste disposal space allocated without penalty to each nuclear generating station under the Low Level Radioactive Waste Policy Amendments Act.

disposal capacity The ability to accept waste for disposal. (This normally refers to a state's completed and operating disposal site with space available to receive additional waste for disposal.)

disposal volume The volume of radioactive waste being shipped for disposal. This is calculated using the exterior dimensions of the package, and it is, therefore, typically greater than the interior volume.

dose A general term denoting the quantity of radiation or energy absorbed. For special purposes, it must be qualified (Radiological Health Handbook. US Department of Health Education and Welfare, 1970).

dose rate A term denoting the rate at which radiation dose is absorbed. See dose.

DOT US Department of Transportation.

dry active waste Dry, solid, low level radioactive waste.

emergency allocations Special allocation of waste burial volume allotted under the provisions of the Low Level Radioactive Waste Policy Amendments Act.

EPA US Environmental Protection Agency.

excess capacity See surge capacity.

FSAR Final Safety Analysis Report

ft^3 Cubic feet. Also abbreviated *cf.*

generation volume The volume of waste measured before any volume reduction processing or conditioning other than collection.

IE The Inspection and Enforcement branch of the NRC.

important to safety 10CFR50, Appendix A, says that structures, systems and components that are important to safety are those that "provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public."

license amendment As used in this document, this is an amendment to a nuclear plant operating license issued under 10CFR50.

LLW Low level waste.

LLRW Low level radioactive waste; more commonly referred to as simply LLW.

LLRWPAA Low Level Radioactive Waste Policy Amendments Act of 1985.

Low Level Radioactive Waste Policy Amendments Act of 1985 (LLWPAA)
A law passed by the US Congress which outlines state and regional responsibilities for the disposal of low level radioactive waste. The LLRWPAA also establishes minimum utility waste disposal volumes from 1986 through 1992 and establishes allowable disposal volume surcharges which may be levied against nuclear stations located in unsited compact regions.

LWR Light water reactor, any water cooled reactor except a heavy water cooled reactor.

mCi Abbreviation for millicuries, a measurement of radioactivity.

non-sited compact region From the Low Level Radioactive Waste Policy Amendments Act, any area of the United States which is not a sited compact region.

NRC US Nuclear Regulatory Commission.

packaged volume The volume of waste as it is packaged ready for disposal. This includes the volume of the burial containers.

pCi Abbreviation for picocuries, a measurement of radioactivity.

planned capacity The volume *and* curies of radioactive material which is intended to be stored in an interim storage facility. This includes the expected waste to be generated by the specific nuclear plant during the anticipated storage period plus any expected surge or excess capacity.

PWR Pressurized water reactor.

radwaste Radioactive waste.

Reg Guide See Regulatory Guide.

Regulatory Guide One of a series of documents published by the NRC which identify one acceptable method of performing some required task or function.

Safety Analysis Report A report developed by the utility as part of application for its operating license. The report discusses all of the issues important to the safe operation of the plant, and it forms the primary basis for the plant's technical specifications.

safety related Important to safety. 10CFR50, Appendix A says that structures, systems and components that are important to safety are those that "provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public."

SAR Safety Analysis Report

showing Document, drawing, design physical structure, commitment, certified action plan, or other certification which is intended to demonstrate (show) that a particular course of action will be or has been pursued.

sited compact region From the Low Level Waste Policy Amendments Act, a compact region in which there is located one of the regional disposal facilities at Barnwell, in the state of South Carolina, or Richland in the state of Washington.

sludge Wet particulate solids.

special nuclear material According to10CFR20.3 "special nuclear material" means: (i) plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of Section 51 of the act, determines to be special nuclear material, but does not include source material' or (ii) any material artificially enriched by any of the foregoing but does not include source material." Reactor fuel is special nuclear material.

stabilization The process of converting a non-solid waste form, such as resin beads or filter media, into a stable and solid monolith. A typical example would be to mix resin with cement to form a concrete monolith.

steam reforming As used herein, this is actually a combination pyrolysis/steam reforming process which uses a combination of dry heat for thermal destruction and superheated steam to reform the resultant carbonized product, thereby releasing the carbon as CO_2.

surge capacity The additional volume and curies of radioactive material included in the planned capacity of an interim storage facility and which is intended to accommodate unusually large amounts of waste due to unexpected plant operations.

Technical Specifications Part of the operating license of NRC licensed nuclear plants.

uCi Abbreviation for microcuries, a measurement of activity.

unsited compact A group of states that have entered into a compact under the low level waste policy amendments act, but have not yet selected a disposal site.

unsited region See non-sited region.

50.59 review A review to assure that a facility or procedure change, or a proposed test experiment, is permissible under 10CFR50.59. The 50.59 review essentially calls for a determination of whether the proposed change, test or experiment involves a change in the facility technical specifications or an unreviewed safety question.

C
STANDARD TESTS FOR SCREENING AND SELECTING COATINGS

Laboratory Application Tests

ASTM D562	*Consistency of paints using the Stormer Viscometer*
ASTM D 1640	*Test methods for drying, curing, or film formation of organic coatings at room temperature*
ASTM D2S01	*Leveling characteristics of paint for draw-down method*
ASTM D4212	*Viscosity by Dip- Type Cups*
ASTM D4400	*Sag resistance of paints using a multi-notch application*

Laboratory Physical Property Tests

ASTM D1737	*Test method for elongation of attached organic coatings with Cylindrical Mandrel Apparatus*
ASTM D3359	*Method for measuring adhesion by tape test*
ASTM D3363	*Test method for film hardness by pencil test*
ASTM D4060	*Test method for abrasion resistance of organic coatings by the Taber Abraser*
NACE TM-03-S5	*Abrasion resistance testing of thin film baked coatings and linings using the falling sand method*

Field Tests for Immersion Service

ASTM D4619	*Inspection of linings in operating flue gas desulfurization systems*

ASTM G4	*Conducting corrosion coupon tests in plant equipment (under operating conditions) method*

Laboratory Accelerated Screening Tests for Atmospheric Service

ASTM 02246	*Method of testing finishes on primed metallic substrates for humidity-thermal cycle cracking*
ASTM 02247	*Practice for testing water resistance of coatings in* 100 *percent relative humidity*
ASTM 02933	*Corrosion resistance of coated steel specimens (cyclic method)*
ASTM 04585	*Practice for testing the water resistance of coatings using controlled condensation*
ASTM 04587	*Practice for conducting tests on paints and related coatings and materials using a fluorescent ultraviolet-condensation light- and water-exposure apparatus*
ASTM G60	*Method for conducting cyclic humidity tests*
NACE TM-O1-84	*Accelerated test procedures for screening atmospheric surface coating systems for offshore platforms and equipment*

Field Tests for Atmospheric Service

ASTM 01014	*Method for conducting exterior exposure tests of paints on steel*
ASTM G7	*Recommended practice for atmospheric environmental exposure testing of nonmetallic materials*
ASTM G92	*Practice for characteristics of atmospheric test sites*
NACE RP-O2-81	*Method for conducting coatings (paint) panel evaluation testing in atmospheric exposures*

Laboratory Immersion Tests

ASTM *C868*	*Test Method for chemical resistance of protective linings*
ASTM 0543	*Test Method for resistance of plastics to chemical reagents*

ASTM 0870	*Practice for testing water resistance of coatings using water immersion*
ASTM 01308	*Effect of household chemicals on clear and pigmented organic finishes*
ASTM 01540	*Effect of chemical agents on organic finishes used in the transportation industry*
ASTM 03912	*Chemical resistance of coatings used in light water nuclear power plants*
ASTM G 20	*Test method for chemical resistance of pipeline coatings*
NACE TM-01-74	*Laboratory method! for the evaluation of protective coatings used as lining materials for immersion service*
NACE TM-01-83	*Evaluation of internal plastic coatings for corrosion control of tubular goods in an aqueous flowing environment*
NACE TM-01-85	*Evaluation of internal plastic coatings for corrosion control of tubular goods by autoclave testing*

Sources:

1. American Society of Testing and Materials (ASTM), 1987 Handbook of Standards, ASTM, 1916 Race Street, Philadelphia, PA 19103 (Volumes 3.02, 4.05, 6.01, 8.01, and 14.02).

2. National Association of Corrosion Engineers (NACE), Coatings and Linings Handbook, and NACE Standards, NACE, P.O. BOX 218340, Houston, TX 77218.

Programs:

Low-Level Waste Management

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com