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RFP-2862

NATIONAL WASTE TERMINAL STORAGE PROGRAM:

Containment system concepts for transporting Type B quantities of Transuranic Waste

**Rockwell
International**

Energy Systems Group
Rocky Flats Plant

MASTER

Issued September 14, 1979

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UC-71 Transportation of
Property and
Nuclear Materials
DOE/TIC-4500-R67

NATIONAL WASTE TERMINAL STORAGE PROGRAM:
CONTAINMENT SYSTEM CONCEPTS FOR TRANSPORTING
TYPE B QUANTITIES OF TRANSURANIC WASTE

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Chemistry Technology

SUBJECT DESCRIPTORS

Waste Transportation
Radioactive Waste Mgmt
Radioactive Wastes
Radioactive Waste Disposal
Transuranium Elements
Shipping Containers
Transport

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FOREWORD

This report was prepared under an agreement between the Department of Energy (DOE) Operations Offices of Albuquerque and Oak Ridge. This agreement involves two DOE prime contractors: Union Carbide Corporation, Nuclear Division; and Rockwell International, Energy Systems Group. The working agreement was administered by the Office of Waste Isolation (OWI)* and is part of the National Waste Terminal Storage (NWTs) Program. The principal objective of the NWTs Program is to provide facilities in various deep geologic formations at several locations in the United States which will safely isolate radioactive wastes. Proposed Federal regulations would require that such wastes be delivered to a Federal repository for terminal isolation.

The OWI Transportation/Logistics Study addresses problems associated with shipping radioactive wastes to NWTs facilities. The objective of the Study is to help ensure the availability of a viable system to transport radioactive wastes to Federal repositories. In support of this objective, a systems analysis of waste transportation has been performed by Oak Ridge National Laboratory (ORNL). A comprehensive report⁽¹⁾ on this system analysis has been prepared.

Several types of waste materials are expected to be transported to Federal repositories for storage or disposal. These are spent fuel, high-level waste (HLW), intermediate-level waste (ILW), and low-level transuranic-contaminated waste (LLT). This report presents some containment system concepts for transporting LLT wastes.

*Now the Office of Nuclear Waste Isolation (ONWI) at Battelle-Columbus, Columbus, Ohio

ABSTRACT

A series of shipping containment system preliminary concepts for Type B quantities of transuranic waste have been formulated. The concepts were based on hypothetical accident protection requirements, potential waste forms, and selected hardware design/considerations.

The concepts consist of suggested waste system containment configurations and construction material suggestions. Analysis of the concepts, based on such features as fabrication ease and cost, utility, and payload efficiency, revealed that concepts utilizing processed waste forms and/or disposable waste packages to provide a major portion of the required accident protection are most favorable.

1.0 INTRODUCTION

This report presents the results of a study performed under agreement with the Union Carbide Corporation, Nuclear Division. The study was conducted by personnel at the Rocky Flats Plant in Golden, Colorado. The Rocky Flats Plant is operated under contract to the Department of Energy (DOE) by the Energy Systems Group of Rockwell International.

This study was performed to identify concepts for transuranic waste containment during transportation. The concepts were formulated to satisfy the "hypothetical accident" test requirements⁽²⁾ for shipping Type B quantities of transuranic waste. The concepts utilize the approach of having different elements of the waste containment system protect against different accident test requirements. Presented in this report are several preliminary concepts. It is intended that these concepts provide a reference for future detailed designs with advantages and operating flexibility not available with current waste transportation systems.

To provide a uniform understanding of some of the terminology utilized in this report, the drawing presented as Figure 1 should be noted.

2.0 RESULTS AND RECOMMENDATIONS SUMMARY

The results presented in this report can be summarized as follows:

- 1) Several preliminary concepts for waste containment during transportation have been formulated and presented.
- 2) Sixteen viable combinations of dividing Type B accident protection among waste containment system elements have been identified and listed.

FIGURE 1 - GRAPHIC DISPLAY SHOWING TERMINOLOGY USED IN THIS REPORT.

- 3) Containment concepts utilizing "processed waste" to provide a portion of the required accident protection are viable and desirable.
- 4) Containment concepts utilizing "throw-away" accident protection, (i.e. no transport container) have many handling and transportation advantages.

The principal recommendation resulting from analysis of the concepts presented in this report is as follows:

- 1) Detailed waste containment system designs utilizing processed waste and throw-away protection should be developed. Since processed waste will be required to satisfy waste repository requirements, a waste form capable of satisfying both repository and transportation requirements should be utilized.

3.0 SELECTED ISSUES DISCUSSION

When addressing LLT waste packaging and transportation matters, selected peripheral subjects require mention.

3.1 Waste Containment Design Concept Philosophy

Transportation packaging for LLT wastes has traditionally involved two basic concepts. Wastes transported from DOE facilities at Golden, Colorado, and Dayton, Ohio, have utilized a modified railcar as the transport vehicle to provide much of the protection against hypothetical accident test requirements. Even though experience with this concept has been very favorable, a principal concern results from the fact that these railcars have not been subjected to hypothetical accident tests. The concepts presented in this report do not require accident protection from the transport vehicle.

The other basic concept in common use utilizes a transport container to provide accident protection. These containers are typically quite heavy and have poor payload-to-weight ratios. Some of the concepts presented in this report parallel the transport container approach. Analysis, however, reveals that these designs are not necessarily desirable.

In general, railcars and large transport containers can be contrasted to many of the concepts presented in this report. These concepts suggest the development of processed waste forms capable of providing some of the required accident protection. Such processed waste used in conjunction with small lightweight throw-away packages would provide the required accident protection and prevent a return "deadhead" of empty transport containers or railcars.

3.2 Processed Waste Forms

The use of processed waste forms to provide selected accident resistance is, of course, not a novel concept. "Special Form" radioactive material as described in the Code of Federal Regulations⁽³⁾ is defined to have properties that provide resistance to selected accident test requirements. The use of "processed" or "special" waste forms is a logical approach to providing transportation accident resistance because of the anticipated waste form requirements for waste repositories. However, special testing and qualification procedures would be required for processed waste forms to ensure a quality level consistent with the expected protection.

3.3 Waste Assay

One complicating factor associated with the design of waste containment systems is the potential need to assay waste received at a repository. Unusual waste forms and large, thick-walled waste packages will increase the difficulty of assay.

3.4 Waste Retrievability

The ability to retrieve waste placed in repositories is, in part, a function of the waste package design life. Some of the concepts in this report would either use packages with a very short life or no package. The no-package case involves placing loose, processed waste directly in a repository. Both of these cases would require special retrieval equipment.

3.5 Double Containment

The double containment requirement listed in the Code of Federal Regulations⁽⁴⁾ would probably not affect LLT waste shipments. The rules require double containment when greater than twenty curies of plutonium exist per package. Unless one large package was used, no problem would result. Removal of all or almost all plutonium from the wastes would, of course also mitigate the need for double containment regardless of the package size. As a reference, current defense waste shipments from the Rocky Flats Plant typically contain less than one curie of plutonium 239 per fifty-five gallon drum.

3.6 Radiation Shielding

The concepts presented in this report do not consider the possible need for radiation shielding. Shielding needs are, of course, very waste specific and would

be considered in a detailed design.

4.0 CONCEPT FORMULATION APPROACH

The waste containment system concepts described in this report were formulated by considering the following three types of information: 1) Hypothetical accident protection placement among waste containment components, 2) potential waste forms, and 3) waste package and transport container design considerations.

4.1 Protection Placement Options

Sixteen protection placement options were selected from a group of eighty-one protection placement combinations. These eighty-one combinations were combinations of waste containment system components and hypothetical accident conditions and are presented in Appendix A. (Note that the transport vehicle is not considered as a waste containment system component.) The eighty-one combinations were first reduced to sixteen options because of certain practical criteria. For example, many of the options were not viable because of the specified sequence for hypothetical accident testing. The final sixteen options and the basis for eliminating the other sixty-five combinations are presented in Appendix B1 and B2.

4.2 Waste Form Options

As shown in Appendix B2 eleven of the sixteen protection placement options utilize waste to provide a portion of the required accident protection. That is, the waste must be in some "processed form." To satisfy the protection placement options, three generic categories of "processed" waste were defined.

These waste forms were defined, based on the accident protection needed, as follows: 1) Wastes providing puncture, thermal, and immersion resistance; 2) wastes providing thermal and immersion resistance, and 3) waste providing immersion resistance. (Waste requiring no accident protection characteristics is referred to as "unprocessed waste.") Some potential "processed" waste forms are listed in Appendix C. In general, processed waste forms have, as a minimum, properties that prevent "smear" contamination.

4.3. Waste Containment Hardware Design Considerations

Further basis for formulating containment system concepts was a list of containment system design considerations. These considerations and selected possibilities were used to define concept limits and select concept features based on the required accident protection. The list of considerations and selected possibilities is shown in Appendix D.

5.0 WASTE CONTAINMENT SYSTEM CONCEPTS

By combining information from: 1) The sixteen accident-protection placement options, 2) the waste form options, and 3) the waste containment hardware design considerations, a group of twenty-five waste containment system conceptual designs were formulated. A ranking analysis was then performed to segregate the more promising concepts. Specific advantages and disadvantages for the best eight concepts were then listed.

5.1 Concept Formulation

Containment concepts were created by first selecting

one of the sixteen accident-protection placement options. Next, the appropriate waste form and waste containment hardware design possibilities were considered and selected to provide the required protection. The resulting designs are presented as Appendix E. In addition to waste form and the number of containment components, the concepts incorporate variations in size, configuration, material, and wall cross-section.

5.2 Containment Concept Analysis

The resulting concepts were first evaluated for the purpose of overall ranking. The following analysis parameters were used for the evaluation: 1) overall cost, 2) utility, 3) payload efficiency, 4) materials availability, 5) fabrication ease, and 6) operating life. As shown in Appendix F1, a number from 1 (worst) to 3 (best) was subjectively assigned to each analysis parameter for each design. The numbers were then summed to obtain the overall design concept rating. A list showing best-to-worse designs based on the rating score is presented as Appendix F2. The ranked designs were then categorized by waste form and container volume to permit identification of the best designs in each of eight categories. The results of this categorization are shown as Appendix F3. Some advantages and disadvantages of the first design in each of these categories were then listed and are presented in Appendix F4.

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APPENDIX A

Option Number	Containment Components			Number of Components
	Waste	Waste Package	Transport Container	
1	DPTI			One
2		DPTI		↓
3			DPTI	
4	T	DPI		Two ↓
5	P	DTI		
6	D	PTI		
7	I	DPT		
8	DPI	T		
9	DTI	P		
10	PTI	D		
11	DPT	I		
12	PT	DI		
13	DT	PI		
14	TI	DP		
15	DI	PT		
16	PI	DT		
17	DP	TI		
18	T		DPI	
19	P		DTI	
20	D		PTI	
21	I		DPT	
22	DPI		T	
23	DTI		P	
24	PTI		D	
25	DPT		I	
26	PT		DI	
27	DT		PI	
28	TI		DP	
29	DI		PT	
30	PI		DT	
31	DP		TI	
32		T	DPI	
33		P	DTI	
34		D	PTI	
35		I	DPT	
36		DPI	T	
37		DTI	P	
38		PTI	D	
39		DPT	I	
40		PT	DI	
41		DT	PI	
42		TI	DP	
43		DI	PT	
44		PI	DT	
45		DP	TI	

APPENDIX A
(Cont.)

Option Number	Containment Components			Number of Components
	Waste	Waste Package	Transport Container	
46	PT	D	T	Three ↓
47	PT	T	D	
48	DP	T	I	
49	DP	I	T	
50	TI	D	P	
51	TI	P	D	
52	DI	P	T	
53	DI	T	P	
54	DT	I	P	
55	PT	I	D	
56	DT	P	I	
57	PT	D	I	
58	D	PI	T	
59	T	PI	D	
60	D	T	PT	
61	T	D	PI	
62	T	DP	I	
63	T	I	DP	
64	I	DP	T	
65	I	T	DP	
66	D	TI	P	
67	D	P	TI	
68	P	TI	D	
69	P	D	TI	
70	P	DI	T	
71	P	T	DI	
72	T	DI	P	
73	T	P	DI	
74	I	DT	P	
75	I	P	DT	
76	I	PT	D	
77	I	D	PT	
78	P	DT	I	
79	P	I	DT	
80	D	PT	I	
81	D	I	PT	

D = Drop Resistance
 P = Puncture Resistance
 T = Thermal Resistance
 I = Immersion Resistance

APPENDIX B1

**CRITERIA USED TO ELIMINATE SIXTY-FIVE
ACCIDENT-PROTECTION PLACEMENT OPTIONS**

APPENDIX B2

SELECTED PROTECTION PLACEMENT OPTIONS

APPENDIX B1

The eighty-one protection placement options were reduced to sixteen protection placement options using the assumptions listed below. Note that some options are affected by more than one criterion.

One-Component Systems

1. All the required accident protection cannot be placed in the waste. (This eliminates option 1.)

Basis for Criterion

Code of Federal Regulation 49CFR173.394

Two-Component Systems

1. Puncture protection cannot be provided with the inner component except when puncture, thermal, and immersion protection are provided together in that component. (This eliminates options 4, 7, 10, 11, 15, 16, 18, 21, 24, 25, 29, 30, 32, 35, 38, 39, 43, and 44.) .

Basis for Criterion

Hypothetical accident test sequence. Puncture of thermal and/or immersion protection could destroy their protective qualities.

2. Drop protection must be located outboard of immersion protection. This eliminates options 3, 4, 5, 7, 8, 10, 11, 12, 14, 16, 17, 18, 19, 21, 22, 24, 25, 26, 28, 30, 31, 32, 33, 35, 36, 38, 39, 40, 42, and 44.

Appendix B1 (Cont'd)

Basis for Criterion

Hypothetical accident test sequence. Designs providing drop and immersion protection in the same component are judged poor practice.

Three-Component Systems

1. Puncture protection cannot be placed inboard of thermal and/or immersion protection. (This eliminates options 45, 46, 47, 48, 51, 54, 55, 56, 57, 61, 63, 66, 67, 68, 69, 70, 72, 74, 77, 78 and 79.)

Basis for Criterion

Hypothetical accident test sequence. Puncturing of thermal and/or immersion protection could destroy their protective qualities.

2. Drop protection must be provided outboard of immersion protection. (This eliminates options 47, 48, 51, 52, 53, 55, 56, 57, 59, 60, 61, 65, 66, 68, 69, 70, 71, 72, 77, 79 and 80.)

Basis for Criterion

Hypothetical accident test sequence. Immersion protection could be damaged during drop testing if located with or outboard of drop protection.

3. Drop protection must be provided with or outboard to thermal protection. (This eliminates options 45, 47, 48, 51, 52, 57, 59, 63, 65, 66, 68, 69, 76, 79 and 80.)

Basis for Criterion

Thermal protection could be damaged during drop testing if located outboard of drop protection.

Appendix B1 (Cont'd)

4. Thermal protection must be provided with or outboard of immersion protection. (This eliminates options 47, 53, 54, 55, 56, 58, 59, 60, 61, 62, 70, 71, 72, 77 and 79.)

Basis for Criterion

Immersion protection could be damaged during thermal testing if located outboard of thermal protection.

APPENDIX B2

Option* Number	Containment Components			Number of Components
	Waste	Waste Package	Transport Container	
1		DPTI		One ↓
2			DPTI	
3	PTI	D		Two ↓
4	TI	DP		
5	I	DPT		
6	PTI		D	
7	TI		DP	
8	I		DPT	
9		PTI	D	
10		TI	DP	
11		I	DPT	
12	TI	P	D	Three ↓
13	TI	D	P	
14	I	TP	D	
15	I	TD	P	
16	I	T	DP	

D = Drop Resistance
 P = Puncture Resistance
 T = Thermal Resistance
 I = Immersion Resistance

* Note that these numbers do not correspond with the numbers presented in Appendix A.

APPENDIX C
POTENTIAL WASTE FORM OPTIONS

APPENDIX C

Required Accident Protection	Waste Type		
	Sludges & Liquids	Combustible Solids (<1475°F) (ash)	Non-Combustible Solids (>1475°F)
Puncture Fire & Immersion	Vitrified, or Ceramic Mix		
Thermal & Immersion	Vitrified, Ceramic mix, Cemented or pyrolysis slag		Vitrified, Ceramic mix, or Pyrolysis slag
Immersion	Vitrified, Ceramic mix, Cemented, Asphalt mix, Polymer resin mix or Pyrolysis slag		Vitrified, Ceramic mix, Recast metal, or pyrolysis slag

APPENDIX D
WASTE PACKAGE AND TRANSPORT
CONTAINER DESIGN CONSIDERATIONS

ACCIDENT PROTECTION REQUIRED			
DROP ☐	PUNCTURE ☐	THERMAL ☐	IMMERSION ☐

DESIGN CONSIDERATIONS	DESIGN POSSIBILITIES
TRANSPORTATION MODE	HIGHWAY ☐ RAIL ☐ INTERMODAL ☐
WASTE CAVITY SIZE	LARGE ☐ SMALL ☐
SHAPE	ROUND ☐ POLYSIDED ☐
STRUCTURAL ASSEMBLY METHOD	FRAME ☐ FRAME & PANEL ☐ PRESS, STAMP, ROLL, EXTRUDE ☐ ENCAPSULATED ☐
WALL CROSS SECTION	NONE ☐ ONE LAYER ☐ MULTILAYER-OUTER ☐ SANDWICH-OUTER ☐ -INNER ☐ -MIDDLE ☐ -INNER ☐
MATERIALS AND/OR REQUIRED PROPERTIES FOR CONSTRUCTION	
STRENGTH	HIGH ☐ LOW ☐
QUALITY	HIGH TEMP ☐ LOW TEMP ☐
DUCTILITY	HIGH ☐ LOW ☐

DESIGN CONSIDERATIONS (CONTINUED)

DESIGN POSSIBILITIES

MATERIALS AND/OR REQUIRED PROPERTIES FOR CONSTRUCTION

IGNITION POINT

< 1475°F ☐ > 1475°F ☐ EITHER ☐

MELTING POINT

< 1475°F ☐ > 1475°F ☐ EITHER ☐

IMPACT & PUNCTURE

HIGH TRANSITION TEMP. ☐ EXPANDED ☐ MATERIALS ☐ WOOD ☐

RUBBER ☐ PLASTICS ☐

THERMAL

HIGH TEMP COATINGS ☐ VACUUM ☐ AIR SPACE ☐ ABLATIVE ☐

SHAPED ☐ INSULATION ☐

LOW THERMAL CONDUCTIVITY ☐ LOOSE PACKED INSULATION ☐ MASS ☐

HIGH SPECIFIC HEAT ☐

IMMERSION

SHRINK PLASTICS ☐ PLASTIC LINER ☐ CASTABLE PLASTICS ☐

RUBBER ☐ METAL W/SEAL ☐

CLOSURE LOCATION

TOP ☐ SIDE ☐ END ☐

CLOSURE FASTENERS

WELDED ☐ BOLTED ☐ LATCHED ☐ MOLDED ☐

APPENDIX D (Cont.)

APPENDIX E
DESIGN CONCEPTS *

* Note that an interpretation guide for this
Design Concept sheets is presented as Appendix G.

The #1A and #1B concepts incorporate all of the Type B protection into a disposable waste package.

CONCEPT #1A

Type B protection would be provided by a single component disposable, retrievable waste package. Unprocessed waste would be transported. Drop and puncture resistance would be provided by gross and local plastic deformation. Thermal resistance would be provided by a filtered vent. (Wastes would be permitted to burn and combustion gases would be vented thru a filter.) Immersion protection would be provided by leak tight construction. Small to medium package sizes would be necessary to maintain a thin wall design. Parallelepiped shapes would be possible for all sizes. Cylindrical shapes would be possible for smaller volume packages.

SECTIONED SIDE VIEW

TOP VIEW

TOP VIEW

OR

CONTAINMENT COMPONENT		WASTE PACKAGE			
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	FILTERED VENT	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	1) Metal with high ductility characteristics such as low carbon steel.			
	SERVICE TEMP	1475°F to -40°F			
	STRENGTH & DUCTILITY	Moderate strength, high ductility			
VOLUME		Small, 5 ft ³ to medium, up to 125 ft ³			
CLOSURE LOCATIONS		Any face			
CLOSURE METHODS		Welded			
USE		Unprocessed waste compatible with waste package inner surface.			
MODE		Highway, rail, intermodal			

The #1A and #1B concepts incorporate all of the Type B protection into a disposable waste package.

CONCEPT #1B

Unprocessed waste would be transported. This concept is similar to #1A, except drop and puncture protection would be provided by elastic deformation. Thermal resistance would be dependent upon the material of construction. With steel construction, a filtered vent would be utilized. With wood or similar materials, ablation and reduced heat conductivity would provide thermal resistance. Immersion protection would be provided by leak-tight construction. Small to medium package sizes would be necessary for drop and puncture test survival. Parallelepiped shapes would be possible for all sizes. Cylindrical shapes would be possible for smaller sizes.

SECTIONED SIDE VIEW

TOP VIEW

TOP VIEW

OR

CONTAINMENT COMPONENT		WASTE PACKAGE			
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC DEFORMATION	ELASTIC DEFORMATION	FILTERED VENT, INSULATION, ABLATION	LEAK TIGHT
REQUIRED PROPERTIES/MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	1) Rigid steel structure 2) Rigid wood or other ablation material			
	SERVICE TEMP	1475°F to -40°F			
	STRENGTH & DUCTILITY	Moderate to high strength Low ductility			
VOLUME		Small to medium, up to 125 ft ³			
CLOSURE LOCATIONS		Any face			
CLOSURE METHODS		Welded, bolted, adhesive, nailed, heat sealed.			
USE		Unprocessed waste compatible with package inner surface.			
MODE		Highway, rail, intermodal			

The #2A concept incorporates all of the Type B protection into a reusable transport container.

CONCEPT #2A

Type B protection would be provided by a single layer reusable transport container. Unprocessed wastes would be transported. A waste package capable of surviving normal transport conditions would be required. Retrievalability would be a function of the waste package construction. Drop and puncture protection would be respectively provided by extensive and local plastic deformation. Thermal resistance would be provided by a filtered vent. Immersion resistance would be provided by leak-tight construction. Container size would be in the medium range. Container shape would be preferable parallel-piped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER			
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	FILTERED VENT	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	1) Metal with high ductility characteristics such as low carbon steel.			
	SERVICE TEMP	1475°F to -40°F			
	STRENGTH & DUCTILITY	Moderate strength. High ductility.			
VOLUME		Medium, ~125 ft ³			
CLOSURE LOCATIONS		Any face			
CLOSURE METHODS		Bolted, latched			
USE		Unprocessed waste compatible with waste package inner surface.			
MODE		Highway, rail, intermodal			

The #3A and #3B concepts divide the Type B protection between the waste and waste package.

CONCEPT #3A

Type B protection would be provided by a two-component containment system consisting of the package and the form of the waste. Drop resistance would be provided by the waste package and puncture, thermal, and immersion resistance by processed waste. Only processed wastes could be transported. The waste package would be disposable and would provide retrievability. The package would probably be limited to small or medium sizes for drop and puncture resistance. Package shape could be either parallelepiped or cylindrical.

SECTIONED SIDE VIEW

TOP VIEW

TOP VIEW

CONTAINMENT COMPONENT		WASTE PACKAGE	WASTE		
CROSS SECTION (SEE SKETCH ABOVE)		MONOLITH OR LIGHT GAUGE METAL SHELL	PROCESSED		
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC OR EXTENSIVE PLASTIC DEFORMATION	IMPACT AND HEAT RESISTANCE,..... INSOLUBILITY		
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Foam, rubber, plastic, metal	Waste forms such as vitrified ash or ceramic mixes		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	High elasticity or ductility			
VOLUME		Small to medium, up to 125 ft ³			
CLOSURE LOCATIONS		Any face			
CLOSURE METHODS		Monolithic, adhesive, welded			
USE		Processed waste forms providing puncture, thermal, and immersion resistance.			
MODE		Highway, rail, intermodal			

PROTECTION PLACEMENT OPTION #3
CONCEPT #3B
PAGE 1 OF 2

The #3A and #3B concepts divide the Type B protection between the waste and waste package.

CONCEPT #3B

Type B protection would be provided by suspending processed waste in a plastic, foam, or rubber matrix. Drop resistance would be provided by the matrix material and puncture, thermal, and immersion resistance would be provided by the processed waste form. Package size would probably be limited to medium to provide handling ease. Package shape would be any desirable shape compatible with all handling, storage, and repository facilities.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		WASTE PACKAGE	WASTE		
CROSS SECTION (SEE SKETCH ABOVE)		MONOLITH	PROCESSED		
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		Elastic & Plastic Deformation	Impact and heat resistance, Insolubility		
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Foam, rubber, plastic & particle board monoliths	Waste forms such as vitrified ash or ceramic mixes		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	Low strength, high elasticity			
VOLUME		Medium, ~125 ft ³			
CLOSURE LOCATIONS		None			
CLOSURE METHODS		Encapsulation			
USE		Processed waste providing puncture, thermal, and immersion resistance compatible with the waste package material.			
MODE		Highway, rail, intermodal			

The #4A thru #4C concepts are similar to the #3A and #3B concepts in that the Type B protection is divided between the waste and waste package.

CONCEPT #4A

Type B protection would be provided by a single layer disposable waste package and the form of the waste. Drop and puncture resistance would be provided by the waste package while thermal and immersion protection would be provided by the waste form. Only processed wastes could be transported. The waste package would be disposable but would provide retrievability. Package size would be in medium range and package shape could be parallelepiped or cylindrical.

SECTIONED SIDE VIEW TOP VIEW TOP VIEW

OR

CONTAINMENT COMPONENT		WASTE PACKAGE		WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	HEAT RESISTANCE	INSOLUBILITY.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal or foamed polymer		Waste forms such as vitrified ash, ceramic mixes, cemented mixes, and pyrolysis slag	
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Moderate strength, high ductility			
VOLUME		Small to medium, up to 125 ft ³			
CLOSURE LOCATIONS		Any face or end			
CLOSURE METHODS		Welded, bolted, latch, adhesive			
USE		Processed waste providing thermal and immersion resistance			
MODE		Highway, rail, intermodal			

The #4A through #4C concepts are similar to the #3A and #3B concepts in that the Type B protection is divided between the waste and waste package.

CONCEPT #4B

Type B protection would be provided by a single layer waste package and the form of the waste. This concept is similar to #4A, except drop and puncture energy would be absorbed by material crush. Larger package sizes would be possible with this approach.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		WASTE PACKAGE		WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		SECTION CRUSH	LOCAL CRUSH	HEAT RESISTANCE	INSOLUBILITY.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	1) Honeycomb metal 2) Wood		Waste forms such as vitrified ash, ceramic mixes, cemented mixes or pyrolysis slag.	
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Low strength. High crushability.			
VOLUME		Medium, 125 ft ³ to large, 1000 ft ³ .			
CLOSURE LOCATIONS		Any face.			
CLOSURE METHODS		Bolted, adhesive			
USE		Processed waste providing thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #4A through #4C concepts are similar to the #3A through #3B concepts in that the Type B protection is divided between the waste and waste package.

CONCEPT #4C

Type B protection would be provided by a "framed" single layer waste package and processed waste. Drop and puncture resistance are provided by surrounding a core waste package with a fabricated framework. Thermal and immersion resistance would be provided by the processed waste form. The package would be disposable and retrievable. A large package size would be utilized in a parallelepiped shape.

SECTIONED SIDE VIEW

CONTAINMENT COMPONENT		WASTE PACKAGE		WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		FRAME DEFORMATION	STAND OFF	HEAT RESISTANCE	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	1) Metal frame 2) Metal waste package		Waste forms such as vitrified ash, ceramic mixes, cemented or pyrolysis slag.	
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Moderate strength frame. Ductile core.			
VOLUME		Large, up to 1000 ft ³ .			
CLOSURE LOCATIONS		Any face.			
CLOSURE METHODS		Welded, latched, bolted.			
USE		Processed waste providing thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #5A through #5D concepts divide the Type B protection between the waste and waste package similar to the Type #3 and #4 concepts.

CONCEPT #5A

Type B protection would be provided by a single layer waste package and processed waste. Drop, puncture, and thermal resistance would be provided by the single layer while immersion resistance would be provided by the waste. Package size could vary up to medium. Shape could be either parallelepiped or cylindrical. The package would be disposable and retrievable.

SECTIONED SIDE VIEW

TOP VIEW

TOP VIEW

OR

CONTAINMENT COMPONENT		WASTE PACKAGE			WASTE
CROSS SECTION (SEE SKETCH ABOVE)					PROCESSED
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	PROCESSED WASTE	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact and puncture properties.			Waste forms such as vitrified ash, ceramic mixes, cemented, asphalt mixes, polymer resin mixes, pyrolysis slag, or recast metal.
	SERVICE TEMP	1475°F to -40°F			130°F to -40°F
	STRENGTH & DUCTILITY	Medium strength. High ductility.			
VOLUME		Small to medium, up to 125 ft ³ .			
CLOSURE LOCATIONS		Any face.			
CLOSURE METHODS		Welded, bolted, latched.			
USE		Processed waste providing immersion resistance.			
MODE		Highway, rail, intermodal.			

The #5A through #5D concepts divide the Type B protection between the waste and waste package similar to the Type #3 and #4 concepts.

CONCEPT #5B

Type B protection would be provided by a single layer waste package and processed waste. This concept is similar to #5A except drop and puncture resistance would be provided by rigidity instead of plasticity. Thermal resistance would be provided by ablation or a filtered vent depending on the material of construction. Immersion resistance would be provided by the processed waste. The package would be disposable and retrievable. Package size would preferably be larger. Package shape would be parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		WASTE PACKAGE			WASTE
CROSS SECTION (SEE SKETCH ABOVE)					PROCESSED
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC DEFORMATION	ELASTIC DEFORMATION	FILTERED VENT, ABLATION, INSULATION	INSOLUBILITY
REQUIRED PROPERTIES/MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	High strength steel or steel-wood composite.			Waste forms such as vitrified ash, ceramic mixes, cemented, asphalt mixes, polymer resin mixes, pyrolysis slag, or recast metal.
	SERVICE TEMP	1475°F to -40°F			130°F to -40°F
	STRENGTH & DUCTILITY	High strength. Minimum ductility.			
VOLUME		Large, 1000 ft ³			
CLOSURE LOCATIONS		Small face			
CLOSURE METHODS		Welded, bolted.			
USE		Processed waste providing immersion resistance.			
MODE		Highway, rail, intermodal.			

The #6A and #6B concepts divide the Type B protection between the waste and transport container.

CONCEPT #6A

Type B protection would be provided by a single layer transport container and processed waste. Drop resistance would be provided by the single layer. Puncture, thermal, and immersion resistance would be provided by the processed waste. No waste package would be utilized. Special handling equipment would be required, especially at repositories, for transporting and emplacing the waste. Retrievability would also require special removal equipment. Container size would probably be in the medium to large range. Parallelepiped shapes would be preferable for the larger sizes.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE		
CROSS SECTION (SEE SKETCH ABOVE)			PROCESSED		
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	IMPACT RESISTANCE	HEAT RESISTANCE	INSOLUBILITY.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact properties.	Waste forms such as vitrified ash or ceramic mixes.		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	Moderate strength. High ductility.			
VOLUME		Medium, 125 ft ³ to large, 1000 ft ³			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.			
USE		Processed waste providing puncture, thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #6A and #6B concepts divide the Type B protection between the waste and transport container.

CONCEPT #6B

Type B protection would be provided by a single layer transport container. This concept differs from #6A in that the drop resistance would be provided by a rigid structure instead of plastic deformation. As with #6A, no waste package would be utilized and waste emplacement and retrievability would require special consideration. Puncture, thermal, and immersion resistance would be provided by processed waste. Container size would be in the medium range to ensure an acceptable container weight to waste ratio. Container shape would be preferably parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE		
CROSS SECTION (SEE SKETCH ABOVE)			PROCESSED		
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC DEFORMATION	IMPACT RESISTANCE	HEAT RESISTANCE	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good strength such as medium carbon steel.	Waste forms such as vitrified ash or ceramic mixes.		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	Moderate to high strength. Good ductility.			
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.			
USE		Processed waste providing puncture, thermal, and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #7A and #7B concepts are similar to the #6-type concepts in that the Type B protection is divided between the waste and transport container.

CONCEPT #7A

Type B protection would be provided by a single layer transport container and processed waste. This concept is similar to #6A and #6B except both the drop and puncture resistance would be provided by the processed waste. No waste package would be utilized and waste handling and retrievability would require special consideration such as #6A and #6B. Container size could range from medium to large. Container shape would be limited to parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER		WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	HEAT RESISTANCE	INSOLUBILITY.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact and puncture properties such as low carbon or austenetic stainless steel...		Waste forms such as vitrified ash, ceramic mixes, or pyrolysis slag.	
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Moderate strength. High ductility.			
VOLUME		Medium, 125 ft ³ to large, 1000 ft ³ .			
CLOSURE LOCATIONS		Any face.			
CLOSURE METHODS		Bolted, latched.			
USE		Processed waste providing thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

PROTECTION PLACEMENT OPTION #7
CONCEPT #7B
PAGE 1 OF 2

The #7A and #7B concepts are similar to the #6-type concepts in that the Type B protection is divided between the waste and transport container.

CONCEPT #7B

Type B protection would be provided by a framed single layer transport container and processed waste. Drop and puncture protection would be provided by the frame-work while thermal and immersion protection would be provided by processed waste. No waste package would be utilized and the same retrievability considerations necessary for concept #6A, etc., would apply. Container size would ideally be large and of parallelepiped shape.

SECTIONED SIDE VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER		WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		FRAME DEFORMATION	STAND OFF	POTENTIAL WASTE FORMS SUCH AS VITRIFIED ASH, CERAMIC MIXES, CEMENTED OR PYROLYSIS SLAG.	
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal frame Metal waste package.			
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Moderate to high strength frame. Ductile core.			
VOLUME		Large, 1000 ft ³ .			
CLOSURE LOCATIONS		End			
CLOSURE METHODS		Latched, bolted.			
USE		Processed waste providing thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #8A concept is similar to the #6 and #7 type concepts in that the Type B protection is divided between the waste and transport container.

CONCEPT #8A

Type B protection would be provided by a single layer transport container and processed waste. This concept is similar to the #6 and #7 type concepts except drop, puncture, and thermal resistance would be provided by the transport container. The immersion resistance would be provided by the processed waste. No waste package would be required and the special handling and waste retrievability considerations necessary for #6A, etc., would apply. Container size would preferably be large and of parallelepiped shape.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER			WASTE
CROSS SECTION (SEE SKETCH ABOVE)					PROCESSED
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL DEFORMATION	FILTERED VENT	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metals with good impact and puncture resistant properties.			Waste forms such as vitrified ash, ceramic mixes, asphalt mixes, polymer resin mixes, pyrolysis slag, or recast metal.
	SERVICE TEMP	1475°F to -40°F			130°F to -40°F
	STRENGTH & DUCTILITY	Low to moderate strength. High ductility.			
VOLUME		Large, 1000. ft ³ .			
CLOSURE LOCATIONS		End			
CLOSURE METHODS		Bolted, latched.			
USE		Processed waste providing immersion resistance.			
MODE		Highway, rail, intermodal.			

The #9A and #9B concepts divide the Type B protection between the waste package and transport container.

CONCEPT #9A

Type B protection would be provided by a two-component containment system. The outer component, or transport container, would provide drop resistance. The inner component, or waste package, would provide puncture, thermal, and immersion resistance. Unprocessed waste would be transported. The waste package would be a monolithic matrix which would be retrievable depending on the matrix material degradation. Container size would be in the medium range. Container shape would be parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE		
CROSS SECTION (SEE SKETCH ABOVE)			MIXED MONOLITH		
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC DEFORMATION	LOCAL DEFORMATION	INSULATION	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with high strength properties.	Foam, rubber, plastic, or particle board monoliths.		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	High strength. Moderate ductility.	Low strength. Moderate ductility.		
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.	Encapsulation		
USE		Unprocessed compatible with monolith package material.			
MODE		Highway, rail, intermodal.			

PROTECTION PLACEMENT OPTION #9
CONCEPT #9B
PAGE 1 OF 2

The #9A and #9B concepts divide the Type B protection between the waste package and transport container.

CONCEPT #9B

Type B protection would be provided by a two-component containment system. The outer component, or transport container would provide drop resistance. The inner component, or waste package, would provide puncture, thermal and immersion resistance. Unprocessed waste would be transported. The waste package would be retrievable. The package size would be in the medium range. Parallelepiped shapes would be utilized.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE PACKAGE		
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	INSULATION MASS, HIGH SPECIFIC HEAT	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact properties such as low carbon steel.	Metal with good puncture resistance along with the following properties a. Low thermal conductivity b. Massive heat sink c. High specific heat		
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		
	STRENGTH & DUCTILITY	Moderate strength. High ductility.	Low strength. High ductility.		
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.	Welded, bolted, latched.		
USE		Unprocessed waste compatible with package inner surface.			
MODE		Highway, rail, intermodal.			

The #10A and #10B concepts are similar to the #9A and #9B concepts in that the Type B protection is divided between the waste package and transport container.

CONCEPT #10A

Type B protection would be provided by a two-component containment system. The outer component or transport container would provide both drop and puncture resistance. The inner component or waste package would be a non-metal and provide the thermal and immersion resistance. Combustion gases from a burning waste package would be vented through a filter. The waste package size would be in the medium range. The waste package shape would be parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER		WASTE PACKAGE	
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC DEFORMATION	LOCAL DEFORMATION ENERGY ABSORPTION	INSULATION, FILTERED VENT	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with high strength properties such as austenetic stainless steel.		Low thermal conductivity non-metal such as wood.	
	SERVICE TEMP	130°F to 40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	High strength. Moderate ductility.		Low to high	
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face			
CLOSURE METHODS		Bolted, stud & nut.		Adhesive, nailed.	
USE		Unprocessed waste compatible with package inner surface.			
MODE		Highway, rail, intermodal.			

The #10A and #10B concepts are similar to the #9A and #9B concepts in that the Type B protection is divided between the waste package and transport container.

CONCEPT #10B

Type B protection would be provided by a single layer waste package surrounded by a framework of metal comprising the transport container. Impact and puncture resistance would be provided by the framework while thermal and immersion resistance would be provided by the waste package. The waste package may be retrievable depending on the materials of construction. Package volume would be in the medium to large range. Package size would be parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER		WASTE PACKAGE	
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL DEFORMATION, STANDOFF	INSULATION, MASS, ABLATION, SPECIFIC HEAT	LEAK TIGHT
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact puncture properties such as austenetic stainless steel.		1) Low thermal conducting metals or non-metals (must be rigid). 2) Massive metal heat sink. 3) Thermally ablative material (must be rigid). 4) High specific heat material.	
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	
	STRENGTH & DUCTILITY	Moderate to high strength. Moderate to high ductility.		Low to moderate strength. Moderate to high ductility.	
VOLUME		Medium, 125 ft ³ to large 1000 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.		Bolted, welded, latched.	
USE		Unprocessed waste compatible with the package inner surface.			
MODE		Highway, rail, intermodal.			

PROTECTION PLACEMENT OPTION #11
CONCEPT #11A
PAGE 1 OF 2

The #11A concept is similar to the 9 and 10 concept in that the Type B protection is divided between the waste package and transport container.

DESIGN #11A

Type B protection would be provided by a two-component containment system. The outer component or transport container would provide drop, puncture, and thermal resistance. The inner component or waste package would provide immersion resistance. The waste package may be retrievable depending on the materials of construction. Package size would be in the medium to large range. Package shape would be parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER			WASTE PACKAGE
CROSS SECTION (SEE SKETCH ABOVE)
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL DEFORMATION	FILTERED VENT	ENCAPSULATION
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact and puncture properties.			Foam, rubber, asphalt.
	SERVICE TEMP	1475°F to -40°F			130°F to -40°F
	STRENGTH & DUCTILITY	Moderate strength. High ductility.			
VOLUME		Medium, 125 ft ³ to large 1000 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.			
USE		Unprocessed waste compatible with package monolith material.			
MODE		Highway, rail, intermodal.			

The #12A concept divides the Type B protection among the waste, waste package, and transport container.

CONCEPT #12A

Type B protection would be provided by a three-component containment system. The outer component or transport container would provide the drop resistance. The intermediate layer or waste package would provide the puncture resistance and the waste or inner layer would provide the thermal and immersion resistance. The waste containment volume could range from medium to large. The shape would be principally parallelepiped.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE PACKAGE	WASTE	
CROSS SECTION (SEE SKETCH ABOVE)				PROCESSED	
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC AND PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	HEAT RESISTANCE	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Foam, wood. Metal with good impact properties such as austenetic stainless steel.	Metal with good puncture properties such as low carbon steel.	Waste forms such as vitrified ash; ceramic mixes, cemented or pyrolysis slag.	
	SERVICE TEMP	130°F to -40°F	130°F to -40°F	1475°F to -40°F	
	STRENGTH & DUCTILITY	High strength. Moderate ductility.	Low strength. High ductility.		
VOLUME		Medium 125 ft ³ to large, 1000 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, welded, latched, moulded, adhesive.	Bolted, welded, latched, moulded, adhesive.		
USE		Processed waste providing thermal and immersion resistance.			
MODE		Highway, rail, intermodal.			

The #13A concept is similar to the #12A concept in that the Type B protection is divided among the waste, waste package, and transport container.

CONCEPT #13A

Type B protection would be provided by a three-component containment system. The outer component or transport container would provide the puncture resistance and the intermediate layer would provide the drop resistance. This approach is opposite to the #12A concept. Thermal and immersion resistance would be provided by the waste as with the #12A concept. Other features of this concept are also similar to the #12A concept. No example of this concept is presented.

The #14A concept is similar to the 12 and 13 concepts in that the Type B protection is divided among the waste, waste package, and transport container.

CONCEPT #14A

Type B protection would be provided by a three-component containment system. The outer component or transport container would provide drop resistance. The intermediate component would provide puncture and thermal resistance and the waste would provide immersion protection. The package would be retrievable. Transport container volume would be in the medium range and parallelepiped shapes to be utilized.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER	WASTE PACKAGE		WASTE
CROSS SECTION (SEE SKETCH ABOVE)					PROCESSED
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		ELASTIC AND PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	INSULATION	INSOLUBILITY.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact puncture properties such as austenetic stainless steel.	Woven fiberglass.		Waste forms such as ceramic cement or asphalt.
	SERVICE TEMP	130°F to -40°F	1475°F to -40°F		130°F to -40°F
	STRENGTH & DUCTILITY	Moderate strength. Moderate to high ductility.	Low strength. High ductility.		
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.	Adhesive.		
USE		Processed waste providing immersion resistance.			
MODE		Highway, rail, intermodal.			

The #15A concept is similar to the 12 through 14 concepts in that the Type B protection is divided among the waste, waste package, and transport container.

CONCEPT #15A

Type B protection would be provided by a three-component containment system. This concept is similar to #14A, except the placement of the drop and puncture resistance is reversed. No example is presented.

The #16A concept is similar to the 12 through 15 concepts in that the Type B protection is divided among the waste, waste package, and transport container.

CONCEPT #16A

Type B protection would be provided by a three-component containment system. The outer component or transport container would provide drop and puncture resistance. The intermediate component would provide thermal resistance and the inner component would provide immersion resistance. Processed waste would be transported. The waste package would provide retrievability depending upon the materials of construction. Transport container volume would be in the medium range. Parallelepiped shapes would be used.

SECTIONED SIDE VIEW

TOP VIEW

CONTAINMENT COMPONENT		TRANSPORT CONTAINER		WASTE PACKAGE	WASTE
CROSS SECTION (SEE SKETCH ABOVE)					PROCESSED
PROTECTION PROVIDED		DROP	PUNCTURE	THERMAL	IMMERSION
PROTECTION DESIGN BASIS		PLASTIC DEFORMATION	LOCAL PLASTIC DEFORMATION	INSULATION	INSOLUBILITY
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Metal with good impact and puncture properties such as austenetic stainless steel.		Wood, fiberglass.	Waste forms such as vitrified ash, cemented, asphalt mixes, polymer resin mixes, pyrolysis slag, or recast metal.
	SERVICE TEMP	130°F to -40°F		1475°F to -40°F	130°F to -40°F
	STRENGTH & DUCTILITY	Moderate strength. High ductility.		Low strength. Moderate ductility.	
VOLUME		Medium, 125 ft ³ .			
CLOSURE LOCATIONS		Small face.			
CLOSURE METHODS		Bolted, latched.		Bolted, nailed, adhesives	
USE		Processed waste providing immersion protection.			
MODE		Highway, rail, intermodal.			

APPENDIX F1
EVALUATION SCORES FOR CONTAINMENT CONCEPTS

APPENDIX F2
OVERALL RANKING OF CONTAINMENT CONCEPTS

APPENDIX F3
RANKING OF CONCEPTS WHEN CONSIDERING
WASTE FORM AND CONTAINMENT VOLUME

APPENDIX F4
DESIGN ADVANTAGES & DISADVANTAGES

Concept #		1	1	2	3	3	4	4	4	5	5	6	6	7	7	8
Analysis Parameter		A	B	A	A	B	A	B	C	A	B	A	B	A	B	A
Design/Testing	COSTS	1	1	1	2	2	2	1	1	1	1	2	2	2	1	1
Materials		3	2	2	2	3	2	1	2	2	2	2	2	2	2	2
Fabrication		3	2	3	3	2	3	2	1	3	2	3	3	3	1	2
Generator	UTILITY	2	2	1	2	2	2	3	2	3	3	2	2	2	2	2
Receiver		3	3	1	3	3	3	3	2	3	3	2	2	2	2	2
Mode		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Payload Efficiency		3	1	1	3	2	3	2	2	2	2	2	1	2	1	2
Materials Performance & Availability		2	2	2	3	2	3	3	3	3	2	3	3	3	2	2
Fabrication Ease		3	2	3	3	2	3	2	1	3	2	3	3	3	1	3
Maintenance	LIFE	3	3	2	3	3	3	3	3	3	3	2	2	2	2	2
Obsolescence		3	3	1	2	3	2	3	3	3	3	1	1	1	1	1
TOTALS		29	24	20	29	27	29	26	23	29	26	25	24	25	18	22

APPENDIX F1

Concept #		9	9	10	10	11	12	13	13	15	16					
Analysis Parameter		A	B	A	B	A	A	A	A	A	A					
Design/Testing	COSTS	3	2	1	1	1	2	1	2	1	1					
Materials		2	2	2	2	2	2	2	2	2	2					
Fabrication		2	2	2	1	3	2	2	2	2	3					
Generator	UTILITY	2	1	2	2	2	2	2	1	2	2					
Receiver		2	2	2	2	2	3	2	2	2	2					
Mode		3	3	2	3	3	3	2	3	3	3					
Payload Efficiency		2	2	2	1	2	2	2	1	1	1					
Materials Performance & Availability		1	2	3	2	2	2	2	2	2	2					
Fabrication Ease		2	2	3	1	3	2	2	3	3	3					
Maintenance	LIFE	2	2	2	2	2	2	2	2	2	2					
Obsolescence		1	1	1	1	1	1	1	1	1	1					
TOTALS		22	21	22	18	23	22	20	21	21	22					

APPENDIX F1

(Cont'd)

APPENDIX F2

RANKING	CONCEPT #	SCORE	PROTECTION LOCATION		
			Waste	Package	Container
(Best)					
1	1A	29		DPTI	
	3A	29	PTI	D	
	4A	29	TI	DP	
	5A	29	I	DPT	
2	3B	27	PTI	D	
3	4B	26	TI	DP	
	5B	26	I	DPT	
4	6A	25	PTI		D
	7A	25	TI		DP
5	1B	24	DPTI		
	6B	24	PTI		D
6	11A	23		I	DPT
	4C	23		I	DPT
7	8A	22	I		DPT
	9A	22		PTI	D
	10A	22		TI	DP
	12A	22	TI	P	D
	16A	22	I	TP	D
	14A	21	I	T	DP
	9B	21		PTI	D
8	15A	21	I	TD	P
	2A	20			DPTI
9	13A	20	RI	D	P
	7B	18	TI		DP
10	10B	18		TI	DP

UNPROCESSED WASTE		PROCESSED WASTE					
*Large/ Medium Volume	**Medium/ Small Volume	P,T,I, Protection Provided by Waste		T,I, Protection Provided by Waste		I, Protection Provided by Waste	
		Large/ Medium Volume	Medium/ Small Volume	Large/ Medium Volume	Medium Small Volume	Large/ Medium Volume	Medium/ Small Volume
Concept#	Concept #	Design #	Design #	Design #	Design #	Design #	Design #
11A	1A	6A	3A	4B	4A	5B	5A
10B	1B		3B	7A		8A	16A
	9A		6B	4C		15A	14A
	10A			12A			
	9B			13A			
	2A			7B			

P = Puncture
T = Thermal
I = Immersion

* 125 to 1000 ft³
** 5 to 125 ft³

APPENDIX F3

APPENDIX F4

CONCEPT #11A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	1	One-layer wall. Drop, puncture and thermal pro- tection integral.	May require several test iterations. Filter design re- quired.
Material Costs	2	Container materi- al standard stock.	Encapsulation med- ium probably experience and may development.
Fabrication Costs	3	Should be low.	
Generator Utility	2	Handles unprocess- ed waste.	Must handle and maintain container.
Receiver Utility	2	Throw-away waste package.	Must handle and return container. Assay difficult.
Mode Utility	3	Adaptable to common modes.	
Payload Efficiency	2	Must deadhead container.	
Materials Performance & Availability	2	Materials stan- dard stock.	Vent filter material needed.
Fabrication Ease	3	Simple box structure.	Waste package would require foam & mixing equipment.
Maintenance Life	2	Throw-away waste package. One- layer design.	Filter would re- quire maintenance.
Obsolescence Life	1		Volume inefficient. Vulnerable to changing transport regulations.

Appendix F4 (Cont'd)

CONCEPT # 1A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	1	All protection integral in one component.	Would require sub- stantial develop- ment and testing.
Material Costs	3	Materials stan- dard with excep- tion of vent filter.	
Fabrication Costs	3	Simple box structure.	
Generator Utility	2		Small to medium packages would require grouping for transport.
Receiver Utility	3	Completely dispos- able.	
Mode Utility	3	No restrictions.	
Payload Efficiency	3	No deadhead. Possible high payload/contain- ment weight ratio.	
Materials Performance & Availability	2		Vent filter material needed.
Fabrication Ease	3	Standard metal fabrication techniques would be utilized.	
Maintenance Life	3	No reuseable components.	
Obsolescence Life	3	No reuseable components.	Increased material costs could force design changes.

Appendix F4 (Cont'd)

CONCEPT # 6A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	2	One-layer wall.	Would require testing to minimize wall thickness.
Material Costs	2	Structural material standard stock.	
Fabrication Costs	3	Simple structure.	
Generator Utility	2		Requires processed waste. Requires storage for transport container.
Receiver Utility	2		Returnable transport container. Possible assay difficulties.
Mode Utility	3	No restrictions.	
Payload Efficiency	2		Probably volume inefficient for larger sizes.
Materials Performance & Availability	3	Material standard stock. High temperature resistance not required for transport container.	
Fabrication Ease	3	Box construction.	
Maintenance Life	2		Would require periodic inspection and repair.
Obsolescence Life	1		Vulnerable to regulatory changes and repository design changes.

Appendix F4 (Cont'd)

CONCEPT # 3A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	2		Concept testing required.
Material Costs	2	Should be low.	
Fabrication Costs	3	Simple box structure.	
Generator Utility	2		Processed waste form required.
Receiver Utility	3	Completely dis- posable.	
Mode Utility	3	No restrictions.	
Payload Efficiency	3	Would have high payload/weight ratio.	
Materials Performance & Availability	3	Standard stock.	
Fabrication Ease	3	Vitrification, etc. process required.	
Maintenance Life	3	No reuseable com- ponents.	
Obsolescence Life	2		Waste form subject to regulation changes.

Appendix F4 (Cont'd)

CONCEPT # 4B

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	1		Energy absorbtion package will require development.
Materials Costs	1		Energy absorbtion materials expensive.
Fabrication Costs	2		Possible high depending on design.
Generator Utility	3	Low weight.	Requires processed waste forms
Receiver Utility	3	Throw-away waste package.	
Mode Utility	3	No restrictions.	
Payload Efficiency	2		Package volume possible small.
Materials Performance & Availability	3	High temperature performance not required. Materials generally available.	
Fabrication Ease	2	No close dimensional tolerances.	
Maintenance Life	3	No reuseable components.	
Obsolescence Life	3	No reusable components.	

Appendix F4 (Cont'd)

CONCEPT # 4A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	2		Package development would be required depending on construction material.
Material Costs	2		
Fabrication Costs	3	Simple box structure.	
Generator Utility	2	No returnable components.	Requires processed waste form.
Receiver Utility	3	Throw-away waste package.	
Mode Utility	3	No restrictions.	
Payload Efficiency	3	Volume efficient.	
Materials Performance & Availability	3	Some materials available. High temperature re- sistance not required for waste package.	
Fabrication Ease	3	Waste package dimensions not critical.	
Maintenance Life	3	No reuseable components.	
Obsolescence Life	2		Package design vulnerable to repository acceptance changes.

Appendix F4 (Cont'd)

CONCEPT # 5B

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	1		Would require considerable development.
Materials Costs	2		Expensive throw- away design.
Fabrication Costs	2		Thermal resistance feature in outer layer.
Generator Utility	3	No returnable components.	Requires processed waste.
Receiver Utility	3	Large size. No returnable com- ponents.	
Mode Utility	3	No restrictions.	
Payload Efficiency	2		Low payload/weight ratio.
Materials Performance & Availability	2		Ablative materials needed.
Fabrication Ease	2		Costs could be high depending on design.
Maintenance Life	3	No reuseable components.	
Obsolescence Life	3		Design vulnerable to repository acceptance criteria.

Appendix F4 (Cont'd)

CONCEPT # 5A

Analysis Parameters	Rating from Appendix F1	Advantages	Disadvantages
Design/Testing Costs	1	One-layer wall.	Would require extensive develop- ment and testing.
Materials Costs	2		May require high strength, high ductility material.
Fabrication Costs	2		Could be above normal depending on waste package material.
Generator Utility	3	Low weight.	Requires processed waste form.
Receiver Utility	3	No reuseable components.	
Mode Utility	3	No restrictions.	
Payload Efficiency	2		Could be reduced if substantial additive needed for processed waste.
Materials Performance & Availability	2		Requires waste package material with unusual pro- perties com- binations.
Fabrication Ease	2		Could be above normal depending on waste package material.
Maintenance Life	3	No reuseable components.	
Obsolescence Life	3		Design vulnerable to regulatory changes.

APPENDIX G
DESIGN SHEET INTERPRETATION GUIDE

APPENDIX G

DESIGN SHEET INTERPRETATION GUIDE (X-Sectioned Side View Sketch) (Top View Sketchs)

CONTAINMENT COMPONENT		Name of Applicable Containment Component (Described Below)
CROSS SECTION (SEE SKETCH ABOVE)		Pictorial Description of Wall Layers in Concept Sketch Above
PROTECTION PROVIDED		Refers to four hypothetical accident test conditions in 49CFR173.398C2
PROTECTION DESIGN BASIS		Refers to a material or design feature that provides protection from one or more of the hypothetical accident test conditions.
REQUIRED PROPERTIES/ MATERIALS FOR CONTAINMENT COMPONENTS	MATERIALS	Refers to either specific materials of construction or general construction material requirements.
	SERVICE TEMP	Required operating temperature range of materials of construction.
	STRENGTH & DUCTILITY	Physical properties of materials of construction specified in relative terms. Properties apply at material operating temperatures.
VOLUME		Refers to the available volume for waste packing.
CLOSURE LOCATIONS		Rectangular parallelepiped shapes can have closures on any side specified. Right circular cylinders have closures only on the ends.
CLOSURE METHODS		Refers to method of attaching access cover.
USE		Refers to waste form permitted inside.
MODE		Refers to applicable transportation mode.