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Accession #: D196067027

Document #: SD-WM-ES-382

Title/Desc:

TRADE STUDY FOR THE DISPOSITION OF CESIUM &
STRONTIUM CAPSULES

Pages: 126

MAR 29 1996

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT

No 613850

2. To: (Receiving Organization) Storage and Disposal Project		3. From: (Originating Organization) TWRS Process Design		4. Related EDT No.: NA	
5. Proj./Prog./Dept./Div.: TWRS		6. Cog. Engr.: R. D. Claghorn 373-1610 73520 H5-49		7. Purchase Order No.: NA	
8. Originator Remarks: This document fulfills Westinghouse Hanford Company "double-asterisk" milestone: March 31, 1996, "Issue Cs/Sr Capsule Processing Alternatives Trade Study."				9. Equip./Component No.: NA	
11. Receiver Remarks:				10. System/Bldg./Facility: NA	
				12. Major Assm. Dwg. No.: NA	
				13. Permit/Permit Application No.: NA	
				14. Required Response Date: 3/29/96	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-WM-ES-382	-	0	Trade Study for the Disposition of Cesium and Strontium Capsules	NA	1,2	1	

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec. 12.7)		1. Approval	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)										(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
1	1	Cog. Eng. R. D. Claghorn	<i>[Signature]</i>	3/29/96	H5-49						
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		Safety									
		Env.									

18. <i>[Signature]</i> R. D. Claghorn Signature of EDT Originator		19. <i>[Signature]</i> R. J. Muskowsky Authorized Representative for Receiving Organization		20. <i>[Signature]</i> J. S. Garfield Recognized Manager		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
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Trade Study for the Disposition of Cesium and Strontium Capsules

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U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 613850

UC: 630

Org Code: 73520

Charge Code: D5222

B&R Code: EW3130010

Total Pages: 126

Key Words: cesium, strontium, capsules, high-level waste, vitrification, overpacking

Abstract: This trade study analyzes alternatives for the eventual disposal of the cesium and strontium capsules currently stored at the Waste Encapsulation and Storage Facility as by-product. However, for purposes of this study, it is assumed that at some time in the future, the capsules will be declared high-level waste and therefore will require disposal at an offsite geologic repository. The study considered numerous alternatives and selected three for detailed analysis: (1) overpack and storage at a high-level waste canister storage building, (2) overpack at the high-level waste vitrification facility followed by storage at a high-level waste canister storage building, and (3) blend capsule contents with other high-level waste feed streams and vitrify at the high-level waste vitrification facility.

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V. L. Burkland 3/27/96
Release Approval Date

Approved for Public Release

**TRADE STUDY FOR THE
DISPOSITION OF CESIUM
AND STRONTIUM
CAPSULES**

March 1996

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Prepared for
U.S. Department of Energy
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EXECUTIVE SUMMARY

This trade study analyzes alternatives for the eventual disposal of the cesium and strontium capsules currently stored as by-product at the Waste Encapsulation and Storage Facility. However, for purposes of this study, it is assumed that at some time in the future, the capsules will be declared high-level waste and therefore will require disposal at an offsite geologic repository. The study considered numerous alternatives and selected three for detailed analysis: (1) overpack and storage at a high-level waste canister storage building, (2) overpack at the high-level waste vitrification facility followed by storage at a high-level waste canister storage building, and (3) blend capsule contents with other high-level waste feed streams and vitrify at the high-level waste vitrification facility. Two no-action scenarios--continued wet storage at the Waste Encapsulation and Storage Facility or dry storage at a high-level waste canister storage building--are presented to provide a basis for the timing and duration of the capsule disposition alternatives.

The study shows that the cost of disposing the equivalent of about 250 canisters of high-level waste dominates over the cost of incorporating the cesium and strontium within high-level waste glass. The study also shows that incorporating the capsule disposition process (overpacking or vitrification) as an addition to either the interim storage facility or as an addition to the high-level waste vitrification facility is much less costly than building a standalone facility, which is the current project baseline. Additionally, assuming that future onsite transportation costs are similar to the current cost of transporting capsules, an overpack operation at an interim storage facility would provide a significant amount of

savings in transportation versus overpack at the vitrification facility.

With regard to onsite worker safety and secondary waste generation, the vitrification of capsule contents is an inherently messy, albeit short-term, operation. The vitrification alternative would create both solid and liquid secondary wastes. The metallic capsule containers would be separated from their contents and shredded for size reduction, thereby creating about 100 drums of remote-handled waste for burial. Removing chloride from the cesium salt would create an additional 115 drums of chloride-loaded ion-exchange resin that would require disposal as mixed waste. The decontamination of the capsule disassembly equipment and cell would create liquid wastes. In contrast, an overpacking operation would be expected to create very little secondary wastes.

With regard to offsite safety, the glass made with the vitrification alternative is much more stable than the current halide (salt) form of cesium and strontium. The corrosion of the capsules due to their contact with the halide contents is highly dependent on the types and quantities of impurities that reside within the capsules. There is insufficient knowledge about these impurities, however, to obtain a definitive determination of how long the capsules will remain intact in an interim storage environment and after disposal in the geologic repository.

Table ES-1 presents a summary of the findings of this study as a function of the performance measures chosen to measure each alternative.

Table ES-1. Alternatives by Performance Measure Matrix.

Performance measure	Alternatives		
	Overpack and store at a high-level waste Canister Storage Building	Overpack at the High-Level Waste Vitrification Facility and store at a Canister Storage Building	Vitrify capsule contents at the High-Level Waste Vitrification Facility
Total capital cost	18	18	22
Total expense	80	100	27
Total life-cycle cost (in 1995 \$ millions)	98	118	49
Schedule	The capsules can be overpacked within three years during the operation of a full-scale canister storage building	The capsules can be overpacked within three years during the operation of a full-scale vitrification facility	The capsule contents can be vitrified within three years during the operation of a full-scale vitrification facility
Operability	An overpacking operation would be relatively simple	An overpacking operation would be relatively simple	A vitrification operation is more complex than overpacking but it does not require complicated machinery
Maintainability			The high degree of contamination would make it more difficult to repair equipment
Onsite safety	Overpack at the interim storage location eliminates a transportation step		Requires opening of capsules and generating secondary wastes
Offsite safety	The halide waste form is not as stable as the glass waste form. (The repository has yet to respond to Hanford's request for a determination of halides as an acceptable waste form.)	The halide waste form is not as stable as the glass waste form	
Environmental acceptability	Fewer effluents than vitrification; offsite acceptability is uncertain	Fewer effluents than vitrification; offsite acceptability is uncertain	Glass waste form is more acceptable than salt waste form
Technical maturity	Regulatory uncertainty with regard to the halide waste form and estimates of capsule corrosion	Regulatory uncertainty with regard to the halide waste form and estimates of capsule corrosion	Uses proven technology
Complexity of interfaces	Requires complicated interface with the repository to determine if halides will be acceptable and to determine if an overpack is required	Requires complicated interface with the repository to determine if halides will be acceptable and to determine if an overpack is required	Produces a standard high-level waste form; no additional Hanford-repository interface required

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LIST OF TERMS

BAT/AKART	Best Available Technology/All Known, Available and Reasonable methods of prevention, control, and Treatment
BUSS	Beneficial Uses Shipping System
CAEM	Continuous airborne effluent monitor
CAM	Continuous air monitor
CCM	Cold crucible melter
CCTV	Closed-circuit television
CSB	Canister Storage Building
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FY	Fiscal year
HEPA	High-efficiency particulate air
HLW	High-level waste
HVAC	Heating, ventilating, and air conditioning
HWVP	Hanford Waste Vitrification Plant
ISB	Interim Safety Basis
LETF	Liquid Effluent Treatment Facility
MCO	Multiple Canister Overpack
MFAT	Melter feed adjustment tank
MPC	Multipurpose container
MYPP	Multi-year Program Plan
NCAW	Neutralized current acid waste
NEPA	<i>National Environmental Policy Act of 1969</i>
NRC	U.S. Nuclear Regulatory Commission
NWPA	<i>Nuclear Waste Policy Act of 1982</i>
OCRWM	Office of Civilian Radioactive Waste Management
PNNL	Pacific Northwest National Laboratory
QA	Quality Assurance
RGQT	Recycled glass quench tank
SAR	Safety Analysis Report
STP	Standard temperature and pressure
TEC	Total Engineered Cost
TEDF	Treated Effluent Disposal Facility
TIG	Tungsten-inert gas
TOE	Total operating efficiency
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
TRS	Technical Requirements Specification
TWRS	Tank Waste Remediation System
WESF	Waste Encapsulation and Storage Facility
WHC	Westinghouse Hanford Company

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TRADE STUDY FOR THE DISPOSITION OF CESIUM AND STRONTIUM CAPSULES

1.0 STATEMENT OF DECISION

This Alternative Generation and Analysis identifies and analyzes alternatives for the final disposition of cesium and strontium capsules. These capsules are currently stored at or will be returned to the Waste Encapsulation and Storage Facility (WESF) at the Hanford Site. Two decisions are under consideration for this trade study:

- The waste form--either halide salt (its current form) or glass
- The host facility for capsule processing.

The alternatives presented for these decisions are analyzed against performance measures to select the preferred alternatives for further definition as part of the engineering process.

1.1 UNACCEPTABLE INITIAL STATE

The initial, unacceptable state as defined by the *Tank Waste Remediation System Mission Analysis Report* (Knutson 1995) is onsite storage of cesium and strontium capsules at WESF. This state is unacceptable because the lifetime integrity of the capsules is uncertain and the cost of this type of storage is very high. Figure 1-1 provides a summary of the capsule data as of July 1995.

Figure 1-1. Cesium and Strontium Capsules.

Cesium and Strontium Capsules

- WESF constructed in 1976
- Capsules filled between 1976 and 1985
- 1577 Total CsCl capsules produced, as of 7/95
 - 1270 Stored at WESF
 - 248 Cut or destroyed for study or use
 - 58 Intact but located off-site
- 640 SrF₂ Total capsules produced, as of 7/95
 - 601 Stored at WESF
 - 30 cut or destroyed for study or use
 - 5 Intact and stored at other onsite locations
 - 4 Intact but located offsite
- As of 7/95
 - Total Intact CsCl capsules contain $\sim 196 \times 10^{14}$ Bq (53 MCi) Cs-137 generating 258 kW
 - Total Intact SrF₂ capsules contain $\sim 85 \times 10^{14}$ Bq (23 MCi) Sr-90 generating 154 kW

FIGURE 1-1

Currently there are 1,270 cesium capsules stored at WESF, including two inner capsules and one capsule with a damaged outer weld currently stored in WESF's F Cell. Twenty-five capsules are planned to be returned from a private irradiator in Lynchburg, Virginia, in fiscal year (FY) 1996 (Gerber 1995). An additional 33 capsules, which are stored at the 327 building, will be returned through FY 1998. Three to four capsules will be generated when residual salt from the cesium legacy program (ADS-8400) is re-encapsulated (four is assumed for planning purposes). This totals to a cesium capsule count of 1,332.

There were 640 strontium capsules produced at WESF; 601 of these are presently stored in the WESF pool cell. Of the 39 strontium capsules remaining, only 4 capsules that are stored at the Nevada Test Site have been committed to be disposed of by other U.S. Department of Energy (DOE) programs. Though there are no formal plans, the remaining capsules have the potential to be returned to WESF and, therefore, are included in the potential inventory to be dispositioned by the Tank Waste Remediation System (TWRS). The total number of strontium capsules then is 636.

These capsules were designed to last hundreds of years. The lifetime integrity of these capsules, however, has now been deemed uncertain due to the unexpected failure of a capsule that was used for commercial purposes. An investigation of the failure could not verify a specific failure mechanism (DOE 1990). The investigation, however, noted important differences in the operating environment at the commercial facility versus the environment provided by the pool storage at WESF. For example, the WESF thermal cycles are more controlled and less severe. The favorable conditions at WESF reduce the concern for failure of the capsules stored in the WESF pools.

The current baseline is that the Transition Projects will maintain the capsules in safe, clean, and stable interim storage at WESF or other temporary storage outside of the TWRS scope until the TWRS Program can prepare them for final disposal.

1.2 ACCEPTABLE END STATE

The current baseline, as identified in the *TWRS Multi-Year Program Plan* (MYPP) (Wojtasek 1995), is that capsules will be prepared for disposal starting in the year 2010. The year 2010 was chosen because at the time of MYPP preparation, it was the projected start date of Phase II of DOE's Alternate Acquisition (privatization) Strategy. The *TWRS Environmental Impact Statement* (EIS) and the MYPP state that the preparation of the capsules will be complete no later than 2028. The year 2028 coincides with the *Hanford Federal Facility Agreement and Consent Order* (referred to as Tri-Party Agreement) (Ecology et al. 1994) Milestone M-51-00, which commits to the completion of high-level waste (HLW) processing.

The preferred disposition must satisfy the acceptable end state for cesium and strontium capsules as defined in the *TWRS Mission Analysis Report* (Knutson 1995). Once the capsules

have been declared a HLW, the end product, i.e., the waste form and the packaging, must comply with the requirements of the federal repository.

This analysis describes the significant technical alternatives that are available to achieve an acceptable end state. At the project level, physical systems, equipment, and facilities are formulated for the purposes of generating cost estimates for each disposition strategy.

1.3 FUNCTIONS AND REQUIREMENTS

The *TWRS Mission Analysis Report* (Knutson 1995) has been transformed into a set of executable functions that are constrained by imposed and derived requirements. The top three levels of these functions, starting at Section 4.2 (TWRS), are defined in the *Tank Waste Remediation System Functions and Requirements* (WHC 1996). If the capsule preparation function is not privatized under the DOE's Alternate Acquisition Strategy, then the functions and requirements at level 4 and below will be defined by a Technical Requirements Specification. If the capsule preparation function is privatized, then a procurement specification will define vendor functions and requirements at level 4 and below.

The functions and requirements document describes the inputs, outputs, and the scope of TWRS Function 4.2.3.6, Prepare Cesium and Strontium Capsules for Disposal. It is important to note that the current scope of this function does not include the transportation of capsules to the capsule preparation facility. Also noteworthy is that this function does not provide mechanisms for receiving anything other than clean, intact, and structurally sound capsules. The interface point and assumptions must be coordinated with and agreed to by the organization (currently, Transition Projects) that stores the capsules at the WESF.

1.4 DECISION ANALYSIS

Figure 1-2 illustrates how this study fits within the decision analysis process. The *Tank Waste Remediation System Functions and Requirements* (WHC 1996) identified the disposition of cesium and strontium capsules as an issue that required an analysis and a decision. A decision plan was formulated by the Action Officer and forwarded to a Decision Board consisting of the Activity Manager for Cesium/Strontium Capsule Disposition, the Project Manager for Storage and Disposal, and the Manager of the Disposal Program, who is also identified as the Decision Maker. The results of this study will be summarized and input to the Decision Board. After some deliberation by the Board, the Decision Maker is expected to choose the baseline architecture for the disposition of cesium and strontium capsules. As the baseline concept is further developed, it will be continuously evaluated against the performance measures defined in Section 4.0 of this study. The results of the continuing evaluation are used to adjust the functions and requirements and to define issues at the lower levels of the architecture tree.

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2.0 GENERATION OF ALTERNATIVES

The Alternatives Generation Analysis starts with the functions, requirements, and the performance measures developed during and for the Mission Analysis and functions and requirements document as described in Section 1.0. This section describes the alternatives that could be made to satisfy the functions, requirements and performance measures. Additionally, this section describes no-action alternatives that would be in place between the present time and the date that the capsule disposition process becomes available. The alternatives are screened for compliance against the measures identified in Section 4.0 and the remaining alternatives are analyzed across the set of decision criteria/performance measures specified by the decision maker.

2.1 ALTERNATIVES GENERATION PROCESS

The process associated with generating and evaluating alternatives is iterative. The process for this study considered the numerous alternatives that have been analyzed in other studies. As the requirements became more detailed and quantified, the alternatives become more complete and refined to allow the initial screening described in Section 3.0. The screening eliminated those alternatives that are considered inadequate (i.e., "go" or "no go" assessment) for the reasons provided. The Alternative Generation and Analysis team consisted of various engineers with representatives from such disciplines as system integration, engineering, and decision analysis.

2.2 ALTERNATIVES

The alternatives considered for this study are illustrated in Figure 2-1. For all alternatives, the capsules are assumed to be intact and structurally sound, as verified by the function that sends the capsules to the capsule disposition facility. This assumption eliminates the need to acquire a duplicate encapsulation facility.

2.2.1 No-Action Alternatives

For the purposes of this study, a no-action alternative is one where the capsules continue to be stored the capsules for an indefinite period of time. Even though no-action alternatives would be outside the scope of the TWRS, this study considers these options because the annual costs associated with storage at the WESF are high and decisions about when to prepare the capsules for disposal impact the overall cost of doing business at the Hanford Site. The no-action alternatives considered for this study include wet storage at the WESF and dry storage either within dry wells or an enclosed facility.

Figure 2-1. Alternatives Considered.

2.2.1.1 Wet Storage. Wet storage for this study is the continued storage at the WESF. Since WESF is near the end of its design life, new upgrades are necessary to extend its mission. The safety basis for the upgrade would be provided by a new safety analysis report.

2.2.1.2 Dry Storage--Dry Wells. Dry storage at Hanford might include storage within dry wells as described in both the *Hanford Defense Waste Environmental Impact Statement* (HDW-EIS, DOE 1988) and the new TWRS EIS (Nankani 1995). The capsules would be taken from WESF, overpacked, and transported to dry wells where they would be stored and monitored until the repository is ready to pick them up.

2.2.1.3 Dry Storage--Enclosed Facility. As an alternative to the dry well storage concept, the capsules are taken from WESF, overpacked, and stored at an enclosed facility such as a Canister Storage Building (CSB). Maintenance; heating, ventilating, and air conditioning (HVAC); utilities; shops; etc.; at the CSB are shared between the overpacking and the storage operations.

2.2.2 Overpack for Disposal

The capsules are assumed to be intact and structurally sound, as verified by the function that sends the capsules to the overpacking facility.

2.2.2.1 Packaging Options. The packaging (for disposal) options considered for this study include a no-packaging option and an option that places the capsules within a container that resembles a HLW glass canister.

Capsules Alone. The need to overpack will be determined by the repository. The DOE Office of Civilian Radioactive Waste Management (OCRWM) may also choose to perform the overpack at the repository. If so, the capsules would be shipped directly to the repository's surface facilities in approved shipping casks.

Emplacement Within a High-Level Waste Type Canister. To facilitate the handling of the capsules as they are transported from the overpacking facility to the interim storage and then the disposal locations, the capsules are placed in a container that resembles a HLW glass canister. Under this option, the overpack not only serves as a handling container, it also provides containment for a capsule that might become damaged during the overpacking operation or otherwise breached during the long-term storage.

2.2.2.2 Host Facility Options. This study considered several options for host overpacking facilities: a standalone facility, the WESF, a CSB, and a vitrification facility.

Standalone Facility. A standalone facility would be one that has the sole purpose of overpacking the capsules in a manner that is acceptable to the repository. The capsules would require receipt, inspection and lag storage following shipment to the facility. The

capsules would be loaded into an overpack similar to the canisters used for HLW glass. The overpacks are then sent to onsite interim storage. All other equipment required to handle the capsules, shops, equipment maintenance, decontamination cells, HVAC, etc., would be provided by the standalone facility.

Waste Encapsulation and Storage Facility. An overpacking operation at the WESF would eliminate the need to ship the capsules from WESF to an overpacking operation. Ancillary equipment such as the HVAC, shops, etc., are all provided by new or existing WESF facilities.

Canister Storage Building. Overpacking the capsules at a canister storage facility includes the receipt, lag storage and overpacking operation. Because its primary function is to store HLW canisters, the CSB already has much of the ancillary equipment and facilities required to support the operation. Since the building includes all of the equipment necessary to retrieve the HLW canisters for eventual shipment to the repository, no additional equipment is required to retrieve overpacked capsules.

Vitrification Facility. Overpacking the capsules at the vitrification facility would require space for the receipt, lag storage, and the overpacking operation. Ancillary equipment such as the HVAC, shops, etc., are already provided by the vitrification facility. Since the building already contains cells for the welding, decontamination and inspection of canisters, no additional equipment or floor space is required for these functions.

2.2.3 Vitrification of Capsule Contents

Under these options, the capsules are transported from the WESF to a vitrification facility where they are opened, their contents extracted, halide(s) are removed from the extracted contents and then the resulting products are vitrified to create a repository-compliant HLW glass.

2.2.3.1 Host Facility. Options for a host vitrification facility include a standalone facility and an addition to a HLW vitrification facility.

Standalone Facility. A standalone facility would be built for the sole purpose of processing the capsule contents. All of the utilities and ancillary facilities would be included.

High-Level Waste Vitrification Facility. Under this option, the HLW vitrification facility hosts the receipt, lag storage and processing operations. The facilities for bringing new equipment (e.g., a new melter) into the facility and loaded drums of solid waste (e.g., a failed melter) out of the facility are modified to also receive the capsules for processing.

2.2.3.2 Halide Separations. Certain types of halides are not readily soluble in molten glass. This is especially true of chloride. This study considers the options of removing only chloride or removing both the chloride and fluoride from the capsule contents.

2.2.3.3 Campaign. After the contents of the capsules have been prepared for vitrification, the prepared feed can either be vitrified alone or the capsule material can be blended with the rest of the HLW feed material.

Single Campaign. Under this option, the capsule material is stored in tanks that are large enough to constitute a single batch of feed to the vitrification process. For a 20 MT/day process, this would be a tank that is about 19 m³.

Blend With High-Level Waste. Under this option, the capsule material is stored only until an existing batch of HLW feed is available to dilute the capsule material.

2.2.4 Onsite Stabilization and Disposal--Subsurface Storage and Disposal

Under this option, the capsules are transported to a overpacking facility, overpacked and then transported to subsurface facility where it is stored and monitored for some extended period of time, and then closed as a near-surface disposal facility.

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3.0 SCREENING OF ALTERNATIVES

Figure 3-1 presents the alternatives selected for further study. The basis for the selection of each alternative is given below.

3.1 NO-ACTION ALTERNATIVES

The no-action alternatives screened for further evaluation include wet storage at the WESF and dry storage either within dry wells or an enclosed facility.

3.1.1 Wet Storage

Even though the continued storage of capsules at WESF would be outside the scope of the TWRS, this study considers this option because the annual costs associated with storage at the WESF are high and decisions about when to prepare the capsules for disposal impact the overall cost of the Hanford cleanup mission. This alternative will be referred to as Case 1.

3.1.2 Dry Storage--Dry Wells

The dry well storage option will not be considered in more detail for this study because the *Alternatives for High-Level Waste Forms, Containers and Processing Systems* (Crawford 1995) concluded that dry wells (boreholes) are a significantly more expensive option than storage at an enclosed facility. The added expense is due, primarily, to the increased land required for dry wells and the additional concrete required for this option. To implement this option, the dry wells would have to be bored far enough apart to prevent the weakening of the walls between the wells. The concrete requirements are greater because each dry well has to bear the weight of the cask, transporter, and glass canister.

3.1.3 Dry Storage--Enclosed Facility

In contrast to the dry well option, dry storage in an enclosed facility requires less land area because the storage tubes can be placed relatively close to each other. Therefore, less concrete is required to implement this option. This alternative has been evaluated, in detail, in a letter report entitled *Cesium and Strontium Capsule Storage at the Canister Storage Building* (Gerber 1995). Even though this option would be outside the scope of the TWRS, this study presents this option because the annual costs associated with dry storage will influence decisions about when to prepare the capsules for disposal. This alternative will be referred to as Case 2A.

Figure 3-1. Options Selected for Further Study.

***Note:**

SrF_2 is not soluble in water. It will be handled as a slurry.

Legend:

CSB = Canister Storage Building

HLW = High-level waste

TWRS = Tank Waste Remediation System

WESF = Waste Encapsulation and Storage Facility

3.2 OVERPACK FOR DISPOSAL

The options screened for the overpack scenario include the overpack concept and the options for a host facility.

3.2.1 Overpack Concepts

If the DOE-OCRWM concludes that no overpack is required, then the no-overpack alternative becomes either Case 1 (continued storage at WESF) or Case 2A (dry storage). Otherwise, the overpack used for this study will be one that provides sufficient heat transfer and resembles a HLW glass canister as shown in Figure 3-2. It is assumed that the HLW glass canister used for full-scale operations is 4.57-m long. A smaller canister, 3-m long, will also be discussed since it is specified as the current standard (see Table 4-2).

3.2.2 Host Facility Options

This study screened several options for host facilities: a standalone facility, overpack at the WESF, overpack at the CSB, and overpack at the vitrification facility.

3.2.2.1 Standalone Facility. This option will not be considered in detail for this study because the *Tank Waste Remediation System Facility Configuration Study* (Boomer et al. 1994) previously concluded that standalone facilities are significantly more costly than facilities that are built as part of a complex. The costs saved by including an overpack facility within a waste processing complex is the result of using equipment (utilities, docks, cranes, storage space, etc.) and operating personnel for more than one purpose. To validate this conclusion, the life-cycle cost estimate presented in the *TWRS Multi-Year Program Plan* (Wojtasek 1995) will be compared to the estimate of the capsule overpack options presented in this study. The MYPP uses an overpack operation at a standalone facility as its basis for capsule disposition.

3.2.2.2 Waste Encapsulation and Storage Facility. The overpacking operation within WESF will not be evaluated in detail in this study. The fact that WESF is an existing facility makes it an attractive option for hosting an overpack operation. According to engineers at the WESF, however, the space and the ports within the facility are not large enough to accommodate a 4.57-m or even a 3-m canister. An even smaller overpack containing two capsules could be used, but according to the letter report *Cesium and Strontium Capsule Storage at the Canister Storage Building* (Gerber 1995) the time required to ship all of the canisters to interim storage would be stretched to eight or nine years assuming that two transport casks are acquired and used during two shifts each day. Adding on to WESF would be possible, but would require some rework of the building in addition to the need for new equipment. In contrast, designing the overpack addition to a new CSB would be more cost efficient since it does not require rework of an existing facility.

Figure 3-2. Overpack Concept.

3.2.2.3 Canister Storage Building. Overpacking at a CSB would eliminate the need to transport overpacks from the overpacking system to the interim storage facility. If dry storage is adopted as a replacement for WESF, then most of the capsule overpacking features would be in place. This alternative will be Case 2B.

3.2.2.4 Vitrification Facility. Overpacking the capsules at the vitrification facility would take advantage of the welding, decontamination, and inspection facilities that are already in place for HLW glass canisters. This alternative will be Case 3A.

3.3 VITRIFICATION OF CAPSULE CONTENTS

Alternatives screened for the vitrification scenario consist of host facility options, options for the removal of halides prior to the vitrification step, and an option to blend the capsule material with the HLW melter feed.

3.3.1 Host Facility

Options screened for a host vitrification facility include a standalone facility and an addition to a HLW vitrification facility.

3.3.1.1 Standalone Facility. This option will not be considered in detail for this study because the total production from this type of facility would be too small to warrant the expense of building a new facility. An addition to a small-scale demonstration facility would be possible. This would certainly require substantial rework of the facility. Designing the addition as part of a new facility, however, would be more efficient since it would not require any rework of a contaminated facility.

3.3.1.2 HLW Vitrification Facility. This alternative would take advantage of the fact that a feed system in a new HLW vitrification facility could be readily designed to accommodate the material from cesium and strontium capsules. This alternative is Case 3B.

3.3.2 Halide Separations

Case 3B will separate chloride from the cesium chloride salts because this process can be readily accomplished with minimal complication. It would be far more complicated to not remove the chloride and deal with the impact of chloride salts on the melter operation. In contrast, the fluoride does not present a problem to the melter and, therefore, it will not be removed from the strontium fluoride material.

3.3.3 Campaign

This study will consider the difference between processing the capsule contents separately versus combining the capsule contents with the HLW melter feed.

3.4 ONSITE STABILIZATION AND DISPOSAL--SUBSURFACE STORAGE AND DISPOSAL

This study will not further consider the disposal of the capsules at the Hanford Site. This alternative is eliminated even though it is very expensive to send waste packages to the HLW repository and the cesium and strontium radioisotopes will decay to near-zero levels within the next 100 years. This option, however, will be evaluated in the TWRS EIS (draft). The TWRS EIS concludes, however, that the strontium and cesium capsules are HLW and their disposal is subject to U.S. Nuclear Regulatory Commission (NRC) requirements for deep geological disposal.

The *Nuclear Waste Policy Act of 1982* (NWPA), as amended (Public Law 97-425, January 7, 1983) provided for the development of repositories for the disposal of HLW and spent nuclear fuel. Presently, the only candidate site being evaluated for construction of a repository for the disposal of HLW and spent nuclear fuel is the Yucca Mountain site in Nevada, as directed by the *Nuclear Waste Policy Amendments Act of 1987*. NWPA requires generators and owners of HLW to provide for the interim storage of such waste until the waste is accepted by the DOE for disposal at a repository (NWPA Section III[a][5]).

4.0 DECISION CRITERIA

This section identifies the performance measures that are used to differentiate between alternatives. These performance measures have evolved from a previous TWRS Leadership Council and were used in previous analyses (Boomer et al. 1994) and a TWRS Decision Board that was established in 1994 to recommend a TWRS facility configuration. The performance measures were selected to envelope and consolidate the various stakeholder values (see Table 4-1).

Table 4-1. Stakeholder Values.

Stakeholder value	Study performance measure
Protect the Columbia River	Indirectly assessed by water use and discharge (although discharges will meet environmental criteria, there may be an impact to migration of existing contamination plumes--this impact is estimated to be minimal)
Deal realistically and forcefully with groundwater contamination	Directly assessed by water discharge, indirectly by operability (i.e., systems that reduce potential for leaks, misroutings, etc.)
Do no harm during cleanup or with new development	Assessed by size and location of facilities.
Transport waste safely and be prepared for problems	Indirectly assessed by quantities of HLW and LLW produced (ie. less waste produced implies less chance of a handling, storage or transport problem)
Use the central plateau wisely for waste management	Assessed by land used by each alternative
Clean up areas of high future use value	Not assessed
Capture economic development opportunities locally	Not assessed
Involve the public in future decisions about Hanford	This study will be available to the public
Protect the environment	Assessed in safety and environmental performance measures
Protect public/worker health and safety	Assessed in safety, operability and maintainability performance measure. Also assessed in terms of quantities of hazardous materials handled (i.e., chemical usage).
Establish management practices that ensure accountability, efficiency and allocation of funds to high priority items	Not assessed
"Get on with the cleanup" to achieve substantive progress in a timely manner	Assessed in terms of capability of alternatives to meet Tri-Party Agreement schedule
Use a systems approach that keeps end points in mind as intermediate decisions are made	Systems engineering approach incorporated as part of study methodology

Table 4-1. Stakeholder Values.

Stakeholder value	Study performance measure
Protect Rights of Native American Indians	Offsite disposal of capsules meets this value.
Cleanup to the level necessary to enable the future use option to occur	Not assessed
Ensure Compliance	Assessed in terms of Environmental Acceptability performance measure and Permitting evaluation.
Enhance technology development	Not applicable, uses existing process.
Reduce Cost	Directly assessed by cost data for the alternatives
Improve waste management	Assessed by quantities of HLW and LLW produced for each alternative and by qualitative assessment of secondary wastes generated.
Use Mature Technologies	Assessed qualitatively as Technical Maturity performance measure
Enhance public acceptance	Public input will be solicited for this decision
Use open and fair processes	Systems engineering methodology is used as basis for study and public input will be solicited.
Increase efficiency	Assessed by cost data for each alternative and by quantities of key consumables used (i.e., water, chemicals, etc.)

It is important to note that the performance measures represent a mixture of quantitative and qualitative factors. Some of the performance measures, such as cost, represent directly measurable variables. Other performance measures, such as operability, are much more dependent on the judgement of experienced engineers. Although this study focuses on the more tangible and immediately visible performance measures such as cost and schedule, it should be noted that some of the less tangible performance measures, such as operability and safety, can carry heavy hidden cost penalties.

4.1 COST

To the extent practical, the system, equipment, or component will be evaluated with respect to capital and operating costs. Even though it is outside the scope of TWRS, storage costs at the WESF will be factored into the analysis to determine the timing and the duration of the capsule disposition alternatives.

4.2 SCHEDULE

Schedule impact/risk will be assessed relative to implementation of a given alternative. Schedules to be considered include start-up, production, Tri-Party Agreement, and other internally (WHC) or externally (DOE, regulatory, stakeholder) driven schedules.

4.3 OPERABILITY

Operability of a system is mostly a qualitative measure of the inherent complexity of a system that influences other aspects of operability such as the following:

- Startup and shutdown of the system. This is an important operability issue since most upset conditions occur during startup and shutdown when the system is in a state of flux and unsteady state conditions are prevalent. This is heavily influenced by the number of systems or unit operations involved.
- Process Control. Operability with regard to process control is influenced by the number and type of process control points (including process samples).
- Troubleshooting and response to off-normal conditions. This factor is influenced by the diversity of systems and equipment. Systems that use simple, mature technologies and equipment are favored over novel and unique technologies and equipment for which there is little operating experience.
- Operator Interface. This aspect of operability is influenced by such factors as the level of training required to operate the system and the degree, type, and frequency of operator interaction with the system.

4.4 MAINTAINABILITY

The maintainability of a system can be assessed by evaluating the complexity, reliability, and repairability of the associated equipment and components. Complexity is influenced by factors such as the level of training required to perform maintenance on the equipment, the need for special or unique tools or procedures, design qualities such as features that ease repair, standardized parts and provisions for troubleshooting. Reliability can be directly measured by failure rates/mean time to failure data, but is also associated with frequency of test, calibration, and preventative maintenance procedures. Another key measure of reliability is the impact of failures on the process, including recovery or downtime following a failure. Repairability is influenced by work space factors (interferences, confined work spaces, etc.), location of the equipment, means of repair or replacement (remote or contact maintenance), number and type of personnel required to support repairs, pre-maintenance preparation requirements and post-maintenance impacts such as quantities and types of waste produced and functional test requirements.

For purposes of this report (at the process level), the operability performance measure captures the maintainability issues for the alternatives considered. Therefore, the maintainability performance measure is not evaluated in detail.

4.5 WORKER SAFETY AND PUBLIC HEALTH

To the extent practical and meaningful, alternatives should be compared on the bases of associated hazards and implications for onsite/offsite safety, worker safety, and mission and property protection. Topical areas for consideration include the following:

- **Hazards**
 - Introduction/creation of hazards
 - Ease of hazard prevention
 - Ease of hazard mitigation
- **Offsite/onsite safety**
 - Hazard categorization
 - Safety class
 - Performance category, or seismic criteria
 - Radiological risk acceptance criteria compliance
 - Toxicological risk acceptance criteria compliance
- **Process and industrial safety**
 - Health physics requirements
 - Compliance with DOE 6430.1A and related industry standards
- **Mission and Property Protection**
 - Potential for accident propagation and impacts to other facilities
 - Potential impacts due to accidents initiated at other facilities
 - Implications for recovery from accidents expected to occur during the lifetime of the mission.

4.6 ENVIRONMENTAL ACCEPTABILITY

The environmental (regulatory) impacts of a system can be assessed by evaluating the following factors:

- Liquid effluent generation
- Gaseous effluent generation
- Secondary dangerous waste generation
- Permitting requirements.

Liquid effluent generation is defined as the volume of liquid effluents discharged to the Liquid Effluent Treatment Facility (LETF) and/or the Treated Effluent Disposal Facility (TEDF). Ideally, the volume of liquid effluents should be minimized. The degree of treatment required before discharge to LETF/TEDF is also a factor that should be examined in comparing systems.

Gaseous effluent generation is defined as the rate of emission of regulated pollutants, both radioactive and nonradioactive. Ideally, emission rates should be kept as low as reasonable achievable. The degree of treatment required to meet airborne effluent discharge limits is also a factor that should be examined in comparing systems.

Secondary dangerous waste generation is defined as the quantity of wastes (including mixed wastes) generated as a result of the primary processing operation. Secondary dangerous waste generation should be minimized as much as possible. The extent of in-plant secondary waste treatment facilities and dangerous waste packaging and storage and accumulation areas are factors that should be considered when comparing systems based on secondary waste generation.

Permitting requirements should be evaluated based on the following factors:

- (1) number of permits required, (2) complexity of required permitting documentation,
- (3) potentially required permits or approvals that are unique to the system being examined,
- (4) regulatory obstacles, and (5) impacts of permitting activities on the project schedule.

4.7 TECHNICAL MATURITY

The technical maturity of a process, system, or piece of equipment can be assessed in terms of the following maturity hierarchy (given in descending order of preference):

1. Technologies that are applied on a production scale in the nuclear industry.
2. Technologies that are applied on a production scale in a conventional commercial industry.
3. Technologies that have been demonstrated on a "hot" or nuclear pilot scale using actual feed materials.
4. Technologies that have been demonstrated on a "cold" or non-nuclear pilot scale using simulated feed materials.
5. Technologies that have been demonstrated on a "hot" or nuclear bench scale using actual feed materials.
6. Technologies that have been demonstrated on a "cold" or non-nuclear bench scale using simulated feed materials.

7. Technologies that are supported by studies which are backed by bench scale experiments.
8. Technologies that are supported by conceptual studies which are not backed by bench scale experiments.

In addition to the hierarchy given above, other factors that influence technical maturity or technology assurance include, (1) maximizing flexibility (adaptability for new technologies or mission change), (2) design flexibility or adaptability for incorporating improved technology, and (3) avoiding regulatory uncertainty. With regard to regulatory uncertainty, Table 4-2 provides a listing of the current waste acceptance requirements for the HLW repository.

4.8 COMPLEXITY OF INTERFACES

The complexity of facility and function interfaces is assessed by evaluating the following factors to the extent practical:

- Flowsheet--Compatibility with reference case and complexity introduced by needed changes.
- Utilities--Requirements for support functions and facilities
- Siting/Location--Special requirements or restrictions imposed for siting within the 200 Area or for specific locations within a facility.
- Constructability--Special construction constraints or procedures imposed.

Table 4-2. Current High-Level Waste Repository Waste Acceptance Requirements.

Requirement	Requirement classification or citing	Pertinent values
High-level waste standard form	Derived	Borosilicate Glass*
Total Length	Derived	3.0 m (+0.005, -0.020)*
Canister diameter	Derived	61.0 cm (+1.5,-1.0 cm)*
Maximum weight	Derived	2500 kg
Canister fill height	Derived	at least 80% of empty canister
Maximum total heat generation	Derived	1,500 W per canister at year of shipment
Maximum storage temperature	Derived	400° C
Maximum inert cover gas leak rate	Derived	10 ⁻⁴ atm-cc/sec.
Canister shall be labelled with unique alphanumeric identifier	10 CFR 60.135(b)(4)	
Criticality safety	10 CFR 60.131(b)(7) 10 CFR 71.55	Criticality is not possible unless two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety k_{eff} sufficiently less than 1 with at least 5% margin after allowance for bias in method of calculation, and uncertainty of experiments used to validate measurement method
Chemical composition	Derived	DOE/OCRWM requires chemical composition and crystalline phase projections for the waste form DOE/OCRWM requires oxide compositions for the oxides of elements present in concentrations > 0.5 wt%, and estimate of error.
Canister material	Derived	DOE/OCRWM requires the ASTM alloy specification and composition of the fill canister material
Radionuclide inventory	Derived	DOE/OCRWM requires estimates of total and individual canister inventory of radionuclides (in curies) with half lives > 10 years and are or will be present in concentrations > 0.05% of the total radioactive inventory. The estimates shall be indexed to the year 2015

ASTM = American Society for Testing and Materials

DOE/OCRWM = U.S. Department of Energy/Office of Civilian Radioactive Waste Management

*Other standard high-level waste forms and canisters will be defined in subsequent revisions of the Waste Acceptance System Requirements Document.

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5.0 CASE 1: CONTINUED STORAGE AT THE WASTE ENCAPSULATION AND STORAGE FACILITY

This section describes Case 1, which is the continued storage of the capsules at WESF. This information was taken from the letter report *Cesium and Strontium Capsule Storage at the Canister Storage Building* (Gerber 1995).

5.1 DESCRIPTION

The current baseline plan for the WESF calls for continued storage of cesium and strontium capsules until about the year 2010 (Gerber 1995). Assuming that the HLW option has been exercised during Phase I of the DOE's TWRS Privatization Strategy (DOE 1995), operation of Phase II facilities is scheduled to begin in the year 2011. The goal of Phase II is to vitrify the HLW that remains after Phase I. Vitrification of HLW is to be completed no later than December 2028 to meet Tri-Party Agreement Milestone M-51-00. Using current flow sheet calculations (based on process knowledge and tank characterization data), the target (nominal) volume of vitrified waste totals 9,100 m³ for Phases I and II and a maximum acceptable volume of 12,000 m³. This will require a HLW vitrification plant that produces approximately 8 MT/day (Orme 1995).

Therefore, in Case 1, the capsules could be transferred to the HLW Project around the year 2011. To meet the M-51-00 Milestone, the HLW Project would have to receive the last of the capsules by the year 2028. Therefore, it is assumed that capsules could be stored at WESF through the year 2028.

In the event that the HLW option is not exercised in Phase I privatization, alternative implementation paths will be evaluated to meet the Tri-Party Agreement milestones. Specifically, the Hanford Site must have a HLW pretreatment facility operating by June 2008 to meet Tri-Party Agreement milestone M-50-04 and a HLW vitrification plant operating by December 2009 to meet Tri-Party Agreement Milestone M-51-03.

5.2 SAFETY CONSIDERATIONS AND IMPACTS

To update the WESF safety basis to the current facility configuration and hazards, an Interim Safety Basis (ISB) is being prepared to replace the existing WESF Safety Analysis Report (SAR). The ISB will support graded compliance to DOE Orders 5480.22 and 5480.23 per the Site Implementation Plan for DOE Orders 5480.21, 5480.22, and 5480.23.

The WESF ISB will include a facility description, an accident analysis, interim operational safety requirements, and a safety equipment list. The ISB will serve as the facility safety basis until it can be determined whether a complete Safety Analysis Report (SAR), per DOE Order 5480.23, is required. This work is scheduled to be completed in

1996 with approval in 1997. Costs for the ISB will not be included in WESF life extension costs since the ISB will be completed whether capsules are transferred to the CSB or remain at WESF. The cost to complete a SAR could be \$3 million. This study assumes a SAR will be completed only if capsules remain at WESF.

The WESF Mission Report (Lund 1995) states, "System evaluations and possibly major upgrades will be required at the end of WESF's design life, 2004. The original design lifetime of the WESF facility is presumed to be thirty years. Ten years from now projects must begin to upgrade building infrastructure subsystems (e.g., wiring, piping, controls) before degradation jeopardizes the safety envelope." A cost estimate to complete these life extension projects is included in Section 5.4.

5.3 ENVIRONMENTAL IMPACTS AND PERMITTING REQUIREMENTS

Alternative storage of the cesium and strontium capsules was evaluated under *National Environmental Policy Act of 1969* (NEPA) in the Hanford Defense Waste-Environmental Impact Statement (HDW-EIS). It was acknowledged in the HDW-EIS that much of the material was committed to beneficial use but eventually would be returned to the Hanford Site for appropriate disposition. The return of the capsules was addressed in the Environmental Assessment *Return of Isotope Capsules to the Waste Encapsulation and Storage Facility* (DOE/EA-0942) (DOE 1994). In that document, it was stated:

"Storage at the WESF will continue under the actions selected in the Record of Decision for the Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington (HDW-EIS) (DOE 1987). As stated in the "Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington; Record of Decision," (54 FR 12440) the DOE decided to store encapsulated cesium and strontium wastes in a pool of water at the WESF until a geologic repository is available to receive the capsules for disposal."

Therefore, it is assumed that continued storage of cesium and strontium capsules at WESF is bounded by the HDW-EIS and additional NEPA work is not required.

5.4 COST ESTIMATE TO STORE CAPSULES AT WESF THROUGH FISCAL YEAR 2028.

This section presents a summary of the activities and costs required to keep the WESF operational to the year 2028.

5.4.1 Cost Estimate Summary

The total cost to store capsules in WESF from FY 2004 until FY 2028 is \$392.4 million. Even though the year 2004 is chosen as a trigger point for WESF life extension projects, some of the scope (and cost) of the projects might be reduced or eliminated if the TWRS commits to the acceptance of the capsules early within the Phase II time frame. Table 5-1 identifies the total cost for life extension projects, WESF program management, WESF Operations and Maintenance, WESF compliance activities, completion of a WESF Safety Analysis Report, and deactivation costs. Each of these cost analyses are discussed in detail in the following sections.

Table 5-1. Total Cost to Store Capsules in The Waste Encapsulation and Storage Facility, Fiscal Years 2004 to 2028.

Item	Total cost (millions) fiscal years 2004 to 2028
WESF Program Management Expense Funding (Programmatic)	71.7
WESF Operations and Maintenance Expense Funding (Programmatic)	270.3
WESF Compliance Expense Funding (Programmatic)	6.3
WESF Safety Analysis Report	3.0
WESF Life Extension Projects	40.0
Deactivation--Clean-out WESF Process Cells/K-3 Filter Change Outs	1.1
Total	392.40

5.4.2 Cost and Schedule Assumptions

To provide a total cost/schedule estimate for storage of capsules at WESF between FY 2004 and FY 2028, the following assumptions were made:

1. For the purposes of comparison, storage costs for capsule storage at WESF versus CSB (dry storage) are assumed to begin in FY 2004 after transport of capsules to the CSB is complete.
2. Decoupling projects between WESF and B Plant will be completed even if capsules are transferred to the CSB. See section 5.4.6 for discussion.

3. Project W-252, "Liquid Effluent Treatment and Disposal" will be completed even if capsules are transferred to the CSB. See section 5.4.7 for discussion.
4. A new WESF Safety Analysis Report per DOE Order 5480.23 will be required to store capsules in the WESF pool cells until 2028.
5. The following additional plant projects are required to maintain the WESF safety envelope before potential shipment of capsules to the CSB:
 - A. Gamma Scanner
 - B. Pool Cell Ion Exchange System
 - C. Pool Cell Leak Detection System
 - D. WESF Ventilation Control System Upgrades
 - E. WESF Control Room.

Therefore, these costs are not included in the incremental costs associated with the WESF life extension.

6. K-3 Duct Clean-out will be completed by close of FY 1996. It is assumed this wash-down will effectively clean-out the duct, and two additional K-3 filter change outs will be required before transfer of WESF to the Hanford Surplus Facilities Program.

5.4.3 WESF Operational/Surveillance and Maintenance Costs

The required Operating/Surveillance/Maintenance expense funding to store capsules at WESF until FY 2028 was derived from the FY 1997 WESF Activity Data Sheets using the FY 2001 Planning Level costs. Required funding for the 1KB1, Program Management Activity and the 1KB5, Compliance Activity, was assumed to be 80 percent WESF and 20 percent B Plant. The annual programmatic required expense funding was prorated using a three percent annual escalation factor. Table 5-2 breaks down the funding requirements for each activity down to the cost account level on an annual basis. The total programmatic expense cost to store capsules at WESF from FY 2004 through FY 2008 is \$348.3 million.

Table 5-2. WESF Activity Data Sheet Preparation Programmatic Funding.

Cap	Title	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1KB101	Program management and admin.	905.7	932.8	960.8	989.6	1019.3	1049.9	1081.4	1113.8	1147.3	1181.7	1217.1	1253.6	1291.2
1KB102	Assessments	973.2	1002.4	1032.5	1063.5	1095.4	1128.2	1162.1	1196.9	1232.9	1269.8	1307.9	1347.2	1387.6
1KB103	WESF Training Admin.	87.4	90.0	92.7	95.5	98.4	101.3	104.4	107.5	110.7	114.1	117.5	121.0	124.6
1KBI	Total program management	1966.3	2025.3	2086.0	2148.6	2213.1	2279.5	2347.9	2418.3	2490.8	2565.6	2642.5	2721.8	2803.5
1KB401	WESF safe and compliant OPS	2638.0	2717.1	2798.7	2882.6	2969.1	3058.2	3149.9	3244.4	3341.7	3442.0	3545.3	3651.6	3761.2
1KB403	Maint. of equip, sys. & struc	4575.0	4712.3	4853.6	4999.2	5149.2	5303.7	5462.8	5626.7	5795.5	5969.3	6148.4	6332.9	6522.9
1KB403	Maintain OPS & safety docu.	200.0	206.0	212.2	218.5	225.1	231.9	238.8	246.0	253.4	261.0	268.8	276.8	285.2
1KB4	WESF operations and maintenance	7413.0	7635.4	7864.5	8100.4	8343.4	8593.7	8851.5	9117.1	9390.6	9672.3	9962.5	10261.3	10569.2
1KB501	Environmental compliance	87.4	90.0	92.7	95.5	98.4	101.3	104.4	107.5	110.7	114.1	117.5	121.0	124.6
1 KB502	Compliance support	87.4	90.0	92.7	95.5	98.4	101.3	104.4	107.5	110.7	114.1	117.5	121.0	124.6
1KB5	Total compliance	174.8	180.1	185.5	191.0	196.8	202.7	208.8	215.0	221.5	228.1	235.0	242.0	249.3
All WESF funding		9554.1	9840.8	10136.0	10440.1	10753.3	11075.9	11408.1	11750.4	12102.9	12466.0	12840.0	13225.2	13621.9

Cap	Title	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
1KB101	Program management and admin.	1330.0	1369.9	1411.0	1453.3	1496.9	1541.8	1588.1	1635.7	1684.8	1735.3	1787.4	1841.0	33019.4
1KB102	Assessments	1429.2	1472.1	1516.3	1561.7	1608.6	1656.9	1706.6	1757.8	1810.5	1864.8	1920.7	1978.4	35483.1
1KB103	WESF training admin.	128.4	132.2	136.2	140.3	144.5	148.8	153.3	157.9	162.6	167.5	172.5	177.7	3187.2
1KBI	Total program management	2887.6	2974.2	3063.4	3155.3	3250.0	3347.5	3447.9	3551.4	3657.9	3767.6	3880.7	3997.1	71689.7
1KB401	WESF safe and compliant ops	3874.0	3990.2	4109.9	4233.2	4360.2	4491.0	4625.7	4764.5	4907.5	5054.7	5206.3	5362.5	96179.5
1KB403	Maint. of equip, sys. and struc.	6718.5	6920.1	7127.7	7341.5	7561.8	7788.6	8022.3	8263.0	8510.8	8766.2	9029.2	9300.0	166801.1
1KB403	Maintain ops and safety docu.	293.7	302.5	311.6	320.9	330.6	340.5	350.7	361.2	372.1	383.2	394.7	406.6	7291.9
1KB4	WESF operations and maintenance	10886.2	11212.8	11549.2	11895.7	12252.6	12620.1	12998.7	13388.7	13790.4	14204.1	14630.2	15069.1	270272.5
1 KB501	Environmental compliance	128.4	132.2	136.2	140.3	144.5	148.8	153.3	157.9	162.6	167.5	172.5	177.7	3187.2
1 KB502	Compliance support	128.4	132.2	136.2	140.3	144.5	148.8	153.3	157.9	162.6	167.5	172.5	177.7	3187.2
1KB5	Total compliance	256.8	264.5	272.4	280.6	289.0	297.6	306.6	315.8	325.2	335.0	345.1	355.4	6374.4
All WESF funding		14030.6	14451.5	14885.0	15331.6	15791.5	16265.3	16753.2	17255.8	17773.5	18306.7	18855.9	19421.6	348336.7

5.4.4 WESF Life Extension Costs

The total cost to complete life extension projects to support storage of capsules at WESF until FY 2028 is \$40 million. WESF life extension costs were developed on a system basis. Any projects required to maintain the safety envelope of the facility before FY 2004 were not included in the life extension costs. The required funding to life extend each system was prorated to the required project completion date using the DOE escalation factors applied to the Rough Order of Magnitude estimate prepared on the ICF Kaiser Interactive Estimating System. The estimate is based on component/equipment data/drawings provided from the cognizant engineers.

5.4.5 Deactivation Costs

For purposes of this study, a cost comparison was made between costs required to transition WESF to the Hanford Surplus Facilities Program starting in FY 2004 and costs required to transition in FY 2029. Costs for the Hanford Surplus Facilities Program to complete final deactivation per Section 14, Facility Decommissioning Process, of the Tri-Party Agreement were not included because the end point criteria for deactivation have not yet been defined, and it is likely the schedule to deactivate will not be accelerated significantly if capsules are removed from the facility in 2003. The following two activities are assumed to occur before transfer to Hanford Surplus Facilities:

1. Cleanout the WESF Process Cells--A cost estimate was completed in November 1990 to cleanout D and E Cell to support process tests for the Hanford Waste Vitrification Plant Project (Nguyen 1990). The estimate included removal of all tanks, condensers, instruments, and associated piping. The estimate also included waste burial costs. Cleanout costs for B and C Cells should be comparable. It is assumed cleanout of the remaining cells (A Cell, A Cell Hood, F Cell, and G Cell) would be approximately half the cost for D and E Cells. The total cost to cleanout D and E Cells was \$193,000 in the cost estimate; therefore, the cost to cleanout all the WESF hot cells in FY 1990 dollars is \$482,500 (assuming a three percent correction factor for escalation). The incremental cost to clean out the process cells in FY 2004 versus FY 2029 is \$798,300.
2. Complete two K-3 Filter Change outs--Two new filters were placed on-line in the K-3 WESF canyon ventilation exhaust filter pits in September, 1993. With continued decontamination of the WESF Process Cells and cleanout of the K-3 duct is assumed the source term for the filters will continue to decrease. As a result, it is assumed two filters will be changed out between FY 2004 and FY 2028, and the existing K-3 filters in spare parts will be used. The cost to change out one filter in 1993 was \$45,000. Using a three percent escalation factor, the cost to change out two additional filters is \$210,000.

5.4.6 Isolation of WESF from B Plant (Decoupling)

B Plant is to be transitioned to a stable condition with minimum long term surveillance and maintenance costs. The baseline plan, "Accelerated Hazard Reduction" for B Plant, will accelerate activities with a high rate of return on investment, as measured by risk reduction and economic benefits. Deactivation of applicable B Plant systems will be initiated as the associated hazardous risks are eliminated. At the close of the accelerated hazard reduction program, most of the remaining B Plant systems will be deactivated. Included in the systems to be deactivated are systems that presently support WESF operation.

B Plant supplies cooling water, deionized water for pool cells, accepts low-level liquid waste streams, liquid effluents, and solid waste from WESF. A project to decouple or isolate WESF from B Plant must include replacement of these services. The objective is to deactivate B Plant systems and activate WESF Systems concurrently or transfer B Plant systems to WESF when B Plant no longer requires use of the system. This will avoid the costly maintenance of two systems operating at the same time. The cost to shutdown these systems is paid back within one to two years due to the reduction in required B Plant operation/maintenance/surveillance activities.

The latest date identified in the FY 1997 Activity Data Sheet to complete the decoupling of essential plant support systems supplied from B Plant to WESF is FY 2000. Planning case funding will provide acceleration of this milestone by 12 to 18 months. Since decoupling activities must be complete before the potential transfer of capsules to the CSB, the associated costs will not be included in the option to store capsules at WESF until FY 2028.

5.4.7 W-252 Cost and Schedule Requirements

During January, 1995 the decision was made by the Westinghouse Program Integration Team to terminate Project W-252, "Liquid Effluent Treatment and Disposal." This project provided implementation of Best Available Technology/All Known, Available, and Reasonable methods of prevention, control, and Treatment (BAT/AKART) for the sites liquid effluent streams. However, after reevaluating the effects of an outright termination of project scope, the decision was made to eliminate all portions of the project except for the implementation of BAT/AKART at one facility, B Plant/WESF. The scope of BAT/AKART at the B Plant/WESF facility would install a closed loop cooling system for the WESF pool cells, thereby resulting in a reduction of waste water to the soil column from approximately 5,000 L/min to between 115 and 150 L/min.

The construction for W-252 is scheduled to be initiated in March 1996, with completion in November of 1996. Assuming WESF capsules are transported to the CSB by 2003, savings from elimination of permitting and operating B Pond will be between \$3.5 million to \$7 million.

Current design and construction costs for the implementation of BAT/AKART at the B Plant/WESF facilities are estimated to be \$6.3 million, with annual operating costs predicted to be \$110,000. After review of the cost data it is assumed that W-252 be completed whether capsules are or are not transferred to the CSB. As a result, the cost to complete W-252 will not be considered as part of life extension costs.

6.0 CASE 2A: DRY STORAGE AT A CANISTER STORAGE BUILDING

This section presents the data relevant to Case 2A, which is a dry storage option in lieu of the wet storage at WESF. Most of the data for this section were adapted from the *Cesium and Strontium Capsule Storage at the Overpack Storage Building* (Gerber 1995).

6.1 DRY STORAGE OVERPACK

This section presents the functions, requirements and a concept for a dry storage overpack. These functions and requirements (F&Rs) were formulated for this study and are otherwise not a part of the TWRS Functional and Requirements Document (WHC 1996).

6.1.1 Functions and Requirements

Since the requirements for a repository overpack may be quite different than the requirements for the Hanford Site dry storage overpack, the dry storage overpack must be designed to allow recovery of the cesium and strontium capsules for emplacement in a second (disposal) overpack that would be compliant with future repository requirements.

To ensure that the capsules can be recovered from the storage overpack, the capsules should remain intact and structurally sound during the storage period. The acceptable salt/metal temperature interface to inhibit corrosion to an acceptable rate is documented in Appendix A. In summary, it was found that the limits for the salt/metal interface temperatures are 317 °C and 258 °C for CsCl capsules, and 540 °C and 453 °C for SrF₂ capsules for 40-year and 80-year dry storage. Since the capsules emit a significant amount of heat, it is also important for the overpack to dissipate that heat.

It should be noted that the Capsule Recovery Program (WHC ADS-4195) and the Cesium Legacy Program (Pacific Northwest National Laboratory [PNNL] ADS-8400) are initiating a joint venture to re-encapsulate capsules not meeting WESF storage requirements into new WESF type capsules. The re-encapsulation is to be conducted in the 324 Building and is planned to be completed in FY 1998. Subsequent transfer of the re-encapsulation technology and equipment from PNNL to WHC will enable WESF to re-encapsulate cesium capsules after FY 1998, pending funding for construction of equipment.

Consistent with the requirements imposed on HLW glass canisters (WHC 1992), the storage overpack is required to provide the primary containment for the cesium and strontium. The overpack for this case would be designed for short-term (less than 100 years) containment and to facilitate heat transfer whereas the overpack that might be required for disposal (Case 2B and 3A) would be one that would be designed to facilitate handling at a HLW repository and, possibly, for long-term containment. The capsules would be placed,

unopened, in the overpack. The overpack would be placed within the CSB in storage tubes that will act as the secondary containment.

6.1.2 Physical Description

A sketch of the conductive heat design overpack selected for this study is shown in Figure 6-1.

The overpack consists of a solid body of ductile cast iron with a centerline cylindrical void. The centerline void is slightly larger in diameter than the capsules to allow loading of the capsules. The centerline void contains two in-line cesium or strontium capsules (nominally 53 cm each) separated by a 10 cm metal spacer. The bottom 15 cm of the overpack is solid cast iron for shielding purposes. Above the top capsule is another 15 cm of shielding with a metal plug inserted in the centerline void. The handling pintle height is 21 cm (same height as the HWVP canister). This two capsule overpack is 167.5-cm high. The overpack has an outside diameter of 66 cm. The internal centerline cylindrical void is nominally 7.2 cm in diameter to allow a 0.25-cm radial gap between the cesium or strontium capsule and the overpack. The gap is required to allow the capsules to be loaded into the overpack.

Several other metals were considered for the overpack: aluminum, steel, copper, and stainless steel. Ductile cast iron was selected as the metal of choice because it has the following features:

- Moderately good thermal conductivity (interface air gaps between the capsule and inside of the overpack controls the efficiency of heat transfer)
- Low metal cost with no outer stainless steel container required
- Structural strength at the temperature limit
- Acceptance by the NRC as a storage material and a significant body of testing data for this use
- The ability for the overpack to augment shielding requirements during emplacement and storage of the overpack in the tube.

There are two disadvantages associated with ductile cast iron:

- The weight of the overpacks may require a stronger secondary containment tube to resist lateral seismic forces.

Figure 6-1. Conductive Heat Design Overpack.

00900

- A survey of ductile cast iron casting companies in the United States by Chem-Nuclear Systems, Inc., indicated that none had an NRC-approved QA program.

6.1.3 Thermal Analysis

A thermal analysis of the overpack concept was conducted to determine the feasibility of meeting temperature limits. The approach taken in the thermal analysis was to determine both the required air temperature outside of a storage tube to maintain the salt/metal interface temperature no higher than the acceptable limit and the salt/metal interface temperature that would be reached to maintain the air temperature outside of a storage tube no higher than the acceptable limit (65.6 °C) to maintain the storage bay concrete integrity. Due to the limited time frame available conservatism was built into the modeling effort: all decay heat was assumed to remain within the cesium and strontium salt matrixes (gamma decay energy spreading outside the cesium chloride salt was not accounted for); the maximum wattage capsules were placed at the storage bay location that would have the highest air temperature (65.6 °C), and natural convection was assumed for the exterior surface of the storage tubes. The overpacks are assumed to be filled with helium. The maximum capsule wattage examined was 508 W, which is the expected wattage for a single strontium capsule at December 31, 2003. The maximum expected cesium capsule wattage at December 31, 2003, is 212 W. The results of the thermal analysis indicate that a 212-W capsule would be maintained at 295 °C and a 508-W capsule would maintain a salt/metal interface temperature of 374 °C.

6.2 QUANTITY OF OVERPACKS REQUIRED

This section estimates the quantity of overpacks required for dry storage and addresses the feasibility of procuring overpacks similar to the desired concept.

6.2.1 Calculation

Assuming that this overpack will be used for both the cesium and the strontium, the total overpacks required would be 984 (holding 1,332 cesium capsules in 666 overpacks and 636 strontium capsules in 318 overpacks). The slightly less than 168-cm height of the overpack will allow 5 overpacks (also 5 impact absorbers between overpacks) to be placed within each storage tube of the CSB. Assuming no mixing of cesium capsule storage overpacks and strontium capsule storage overpacks in the same tube 198 tubes are required (134 for cesium storage and 64 for strontium storage). Each of the bays in the current CSB concept has 220 storage tube locations. Thus one bay has enough physical capacity to store the entire inventory of cesium and strontium capsules.

6.2.2 Overpack Production/Procurement

Discussions with potential vendors of the overpacks concluded that no American foundries are currently in the business of producing nuclear grade (with appropriate QA) cast iron casks. However, Teledyne Casting Services, Inc., of Leport, Indiana, has experience in producing heavy section (thick walled) cast iron and could produce the desired overpack. The center cavity is created by placing a pipe or tube of the desired diameter within the mold and casting around it. The pipe is left in place as part of the overpack. The top of the overpack would be machined and bolts tapped to mate up with the required metal seal and lid fixture. The lid would also be machined and holes tapped to mate up with the seal and overpack.

Set up time would be approximately 6 months to set up the equipment and get a quality assurance plan in place. Once set up, the production rate would be one overpack per day, 250 days per year. Production of 1,000 overpacks (984 required for two-capsule version to store 1,968 capsules) would take 4 years.

6.3 MODIFICATIONS TO A CANISTER STORAGE BUILDING

This section describes the incremental modifications to a CSB that would be required to overpack (for storage) and store capsules. Items evaluated in the CSB include the shipping/receiving area, shielding, ventilation, structural systems, and special features including storage tubes, overpack handling features, and a capsule handling cell.

6.3.1 Cesium/Strontium Overpack Storage Vault

It is assumed that a vault within the CSB, containing the cesium/strontium capsules, would have its own inlet and exhaust plenum, which would be isolated from the inlet and exhaust plenums for the other vaults containing glass canisters. This approach, with separate cooling flow paths for the cesium/strontium capsules and the glass canisters, is similar to heat load distributions that have previously been evaluated in the *Hanford Waste Vitrification Plant Canister Storage Building Preliminary Safety Analysis Report* (WHC 1992).

6.3.2 Capsule Handling Facilities

The capsule handling facilities consist of a shipping cask receipt and unloading area and a capsule handling hot cell for capsule removal, inspection, and overpack loading.

6.3.2.1 Shipping Cask Receipt and Unloading. Cesium/strontium capsules will be received from WESF at the CSB in one of two shipping casks. It is assumed that shipment of cesium/strontium capsules would occur between shipments of HLW glass. Therefore, equipment and space within the Shipping/Receiving Area will be available for cask handling

operations. The preferred cask for shipment of cesium/strontium capsules is the BUSS R-1 Cask, weighing approximately 15 MT. This cask can be transported by either truck or rail. An alternative cask is the GE 2000 Cask, weighing 15.2 MT. Assuming that the capacity of the Shipping Cask Handling Crane is 36 MT, the CSB will be capable of handling either cask.

Upon arrival at the CSB, the truck or rail mounted shipping cask will enter the Washdown Area for a series of operations necessary to prepare the cask for unloading. Since surface radiation fields from either cask are expected to exceed allowable personnel exposure rates permitted for daily operations, the cask will require remote/robotic inspection and preparation for offloading from the transport device. These operations will require overhead or mobile robotic devices and CCTV systems to assess the condition of the casks and remove auxiliary shipping items such as impact limiters and hold-down devices. It is assumed these same robotic devices will be required for handling casks containing HLW glass. Therefore, no incremental equipment, building, or cost impacts are required. Since the onsite HLW cask offloading system would be a new facility, it can be designed to offload a capsule cask using a remote operator. The two types of capsule casks mentioned in this study are designed for hands-on offloading preparation, i.e., removal of tie-downs and impact limiters.

When the shipping cask has completed operations in preparation for unloading, it will be moved into the Shipping/Receiving Area serviced by the 36 MT overhead crane. A lifting fixture will be remotely attached to the cask, and the cask upended to a vertical position. The cask will then be moved and lowered into the same transfer tunnel used to unload HLW casks (see Figure 7-4). The cask will be placed on a powered cart and transferred to positions dedicated to preparing the cask for unloading. A fixture may be placed on the cask to provide a common facility interface with the specific cask being used. The cask transfer cart will have a support frame attached to its base to elevate the top of the shorter capsule cask to the same elevation as the HLW shipping cask. The operations to prepare the cask for capsule unloading include robotic inspection of the cask closure, gas sampling of the cask interior, and the loosening of the cover bolts. When ready for capsule unloading, the cask will be remotely moved to an unloading position underneath a Capsule Handling Hot Cell added to the CSB design. Since the operations to prepare the cask for capsule unloading uses the same equipment and positions as casks containing HLW canisters, there is no major incremental impact in building size or cost from cask handling operations.

6.3.2.2 Capsule Removal and Inspection. A Capsule Handling Hot Cell in the CSB is dedicated to the remote cask unloading, inspection, temporary storage and packaging of cesium/strontium capsules. The hot cell provides two main safety features:

- A shielding barrier between the high radiation field capsules and operators of the remotely controlled equipment.
- A contamination barrier to contain radionuclides that could be released from the capsules during handling and lag storage.

Although the risks of contamination from the capsules are not expected to be high, the hot cell will contain the necessary Zone 1 ventilation systems and HEPA filters to capture any releases. The cell will also be designed with features to accommodate the decontamination of the cell floor, walls, and equipment if necessary.

An unloading port at the west end of the cell will interface with the shipping cask such that an air-tight enclosure will be assured before opening the unloading port and exposing the cask interior to the cell environment. This enclosure will also ensure that the cask exterior is not exposed to airborne contamination during the entire unloading operation. A pneumatic or mechanical seal underneath the cell unloading port will be activated when the shipping cask is in position to provide a contamination barrier between the exterior of the cask and the hot cell environment, including the interior of the cask. A support frame may also be required on the transfer cart to position the capsule shipping cask at the elevation required for mating and sealing with the hot cell port. A laydown area is provided in the cell adjacent to the unloading port for placement of the cask cover.

Handling of the capsules in the cell will use an overhead PaR electro-mechanical manipulator with CCTV cameras to provide the operator the necessary viewing required to perform remote operations. The PaR manipulator provides the dexterity and reach necessary to handle cesium/strontium capsules, particularly since they are relatively small and light and do not have a handling fixture. A small hoist may also be mounted on the manipulator bridge to assist in handling and maintenance operations. To supplement the capabilities of the PaR manipulator, three shielding windows and two master-slave manipulators are placed at specific locations in the cell. Additional CCTV cameras with pan and tilt capability can be placed and moved by the overhead manipulator.

The overhead manipulator will unload the cesium/strontium capsules from the shipping cask and transfer them directly to an inspection station or an in cell storage enclosure. A shielding window is provided near the unloading port to provide additional operator viewing of the unloading operations. The in-cell storage enclosure provides a storage capacity of 36 capsules, which is approximately the capacity of three casks. This lag storage capacity provides an important buffer between the cask unloading and the capsule inspection and overpack loading operations occurring downstream. Should an equipment item associated with downstream operations fail or require maintenance, the cask unloading and inspection operations can continue. Conversely, should cask unloading operations be halted, this storage enclosure location permits downstream operations to continue for up to three weeks. Air cooling for capsules stored in the storage enclosure will be designed for the maximum anticipated heat generation load.

The capsule inspection station will be used to perform the visual and remote operations necessary to identify and record the individual capsules and confirm integrity of the capsule before packaging. Confirmation of capsule integrity will ensure that the capsule will not contaminate downstream operations, including the storage overpack interior when packaged.

Personnel at the station will perform operations with a pair of master-slave manipulators supplemented by the overhead PaR manipulator. Viewing of the station operations will be through a shielding window and the in-cell CCTV cameras.

6.3.2.3 Overpack Loading. Upon completion of the operations at the capsule inspection station, the capsule will be transferred through a small transfer air-lock to a overpack loading station at the East end of the cell. The air-lock minimizes the possibility that the storage overpack will be contaminated by potential airborne contamination from the cask unloading operations. Storage overpacks will be brought underneath the East end of the cell on a wheeled transporter, similar in concept to movement of the shipping cask at the opposite end of the cell. Personnel performing overpack loading operations will use a pair of master-slave manipulators to perform loading operations while viewing through a shielding window. Loading operations will also involve placing of spacers with the two capsules loaded into each storage overpack.

The overpack loading station will also include a robotic device for placing of the overpack top after loading and effecting closure of the overpack using bolts. A leak check will be performed using a backfill gas and a pressure monitor. Additional tests verifying closure may also be performed. Upon completion of these tests, the loaded storage overpack will be moved by the transfer cart through the short transfer tunnel to a position directly underneath a port leading to the operating area above the vaults. This same transfer tunnel is used to bring empty overpacks to the loading position.

Empty overpacks will be received, inspected, and stored in the Shipping/Receiving Area. They will be individually transferred into the operating area above the vaults through an airlock. A battery powered cart will travel from a loading position in the cask unloading area, through the airlock, and to a position underneath the overpack handling crane operating in the storage bay. They will then be individually transferred to the loading positions in the hot cell using the same port and transfer cart used to remove them after filling.

6.3.2.4 Summary of the Additional Equipment Required. Table 6-1 lists the mechanical equipment to be added to the CSB for capsule handling, unloading, and packaging operations.

Table 6-1. Additional Mechanical Equipment Required.

Item	Quantity
Capsule cask handling	
Transfer cart/cask adapter	1
Capsule handling hot cell	
Overhead PaR electromechanical	1
Manipulator with closed-circuit television system	1
Master-slave manipulators	2 pair
Shielding windows	3
Capsule storage array (36 capsules)	1
Capsule inspection station	1
Overpack loading, closure, and leak	1
Test station	1
Overpack transfer cart	1

6.3.3 Facility Shielding

The facility shielding studies involved comparisons of the cesium/strontium capsule dose rates to the dose rates of the HWVP shield source overpack. The HWVP shield source overpack was used to originally evaluate the shielding adequacy of the CSB vault. This original evaluation used Monte Carlo Neutron and Photon Transport Code System (MCNP-4) to produce a high-fidelity model of the CSB geometry and source configurations. The MCNP-4 modeling technique is prohibitively time consuming for the current study required for the cesium/strontium capsules. The daughter products of ^{137}Cs ($^{137\text{m}}\text{Ba}$) and of ^{90}Sr (^{90}Y) are included at their appropriate equilibrium concentrations. MicroShield-4¹ was used to perform the comparison studies for the cesium capsules. ISO-PC was used to evaluate the strontium capsules. However, MCNP-4 may be used at a later date to examine cost saving shielding reductions to the CSB.

¹MicroShield-4 is a tradename of Grove Engineering, Inc., Rockville, MD.

6.3.3.1 Storage Vault Adequacy. The HWVP shield source overpack was modeled with MicroShield-4 and found to have gamma dose rates of 7.297×10^7 mrem/h (surface) and 1.135×10^6 mrem/h (4.6 m). The 4.6-m distance is a typical distance from the first row of overpacks to either the inlet or outlet plenum entrance. Since there were a maximum of three overpacks per tube, a conservative estimate would be to multiply the 4.6-m dose rate by a factor of three, which provides a dose rate of 3.405×10^6 mrem/h to compare with a tube filled with cesium/strontium overpacks.

The cesium/strontium capsules will be placed in a cast iron cylinder. The gamma (two cesium capsules) dose rates for the cast iron cylinder is 6.186×10^2 mrem/h (surface) and 1.289×10^1 mrem/h (4.6 m). Since there would be a maximum of five cylinders per tube, a conservative estimate would be to multiply the 4.6-m dose rate by a factor of five, which provides a dose rate of 6.445×10^1 mrem/h. The beta-induced photon (two strontium capsules) dose rates for the same cylinder is 2.2×10^1 mrem/h (surface) and 4.1×10^{-1} mrem/h (4.6 m). Using the same factor of five, the dose rate from one tube filled with strontium cylinders would be 2.0×10^0 mrem/h. Since the dose rate on the surface of the strontium cylinder is so low compared to either the cesium cylinder or the HWVP shield source overpack, further calculations will only be performed on the cesium cylinder. It should be noted that the bare strontium capsule has a calculated contact dose rate of 1.724×10^4 rem/h (ISO-PC) and 2.074×10^4 rem/h (MCNP-4A), which are both considerably less than the 1×10^6 rem/h or more for cesium capsules. If the strontium is contaminated with other radionuclides, then that information should be provided for future studies.

The floor and floor plug shielding is of interest since the additional shielding provided by the cast iron on the sides of the overpacks is very minimal at the top. The gamma (one cesium capsule) dose rates for a bare cesium source (very conservative) is 2.216×10^{-3} mrem/h with a (1.4-m) shield of standard density (2.24 g/cm^3) concrete. This is the original floor plug thickness and it would seem to be adequate for the entire vault. Additional studies should be made to evaluate the plug gap streaming since the cesium overpacks will be loaded closer to the ceiling than were the HWVP overpacks.

The original shielding provided in the CSB should be adequate for the cesium and strontium capsule storage based upon the above calculated dose rates. A preferred placement of the cesium or strontium capsules does not appear to be necessary with the original design. The changing locations of the inlet and exhaust plenums and stacks will need to be evaluated for the cesium and strontium capsules. The original shielding studies for the CSB indicated that placement and configuration of the plenums and stacks could change the dose rates at the operating floor and outside the CSB dramatically.

6.3.3.2 Hot Cell Walls, Floor and Ceiling Shielding. The gamma dose rate from a bare cesium capsule is 8.01×10^8 mrem/h. The capsules will need to be handled within a hot cell to be inserted into the cesium and strontium overpacks. The hot cell walls, floor and ceiling should be a minimum of 1.5-m thick. This thickness allows for multiple capsules to be

located in the cell as well as reasonable sized HVAC ducts for ventilation and health protection.

6.3.3.3 Transport Cask Shielding. Since the surface dose rates for the cesium and strontium overpacks are substantially above 0.2 mrem/h, a shielded transport cask will be needed to transfer the overpacks from the hot cell to the emplacement tubes in the vault. The cast iron cylinder requires a total of 15 cm of steel shielding.

6.3.3.4 Impact Summary. The impact of the facility shielding is covered in the structural section. This includes the main structure of the CSB vault as well as the hot cell walls, floor and ceiling. The transport of the overpacks to the vault is covered in special fixtures in the material handling section. The shielding requirements of the shipping and receiving areas should be adequately handled with the requirement that the cask used to transport the capsules into the facility have a contact dose rate of 200 mrem/h, or less, and that it can be remotely unloaded.

6.3.4 Ventilation System

Storage of cesium and strontium capsules would impact the ventilation system that is designed to remove heat from the storage vaults. Capsule handling operations would also impose additional HVAC requirements at the CSB.

6.3.4.1 Vault Ventilation. The CSB has three underground vaults. Each storage vault has 22 rows of sealed vertical vault tubes. Each row contains ten storage tubes. In the CSB design for storage of HLW, the tubes were supported from the floor and were designed to hold three HLW canisters per tube. The storage tubes were of approximately 69 cm in diameter and were about 10.7-m long. The CSB passive ventilation cooling system was designed to serve all three vaults. The air enters the vault through two raised air inlets, flows through the vault around the storage tubes, and exits the vaults via a common stack. The air flow through the vault is caused by natural draft due to decay heat from the material stored. Each vault was designed for an internal heat load from the HLW up to 660 kW. Extensive heat transfer analysis and computer modeling was performed to assure that the specified glass center line temperature limit was not exceeded. Computational Fluid Dynamics analysis was made to predict temperatures and location of hot spots in the vault caused by air flow eddies.

The total heat load from the storage of cesium capsules is about 228 kW and from strontium capsules is 147 kW based on year 2000 decay heat generation rates. The vault passive ventilation cooling system for the HLW glass logs was designed for a heat load of up to 660 kW.

Insulating concrete will be required for the vault storing cesium/strontium capsules. The preliminary thermal analysis indicates that the salt/metal interface temperature for the cesium/strontium capsules should not exceed the limiting temperature listed above. However, the vault concrete temperature may exceed the 66 °C limit due to radiation from the storage tubes. Therefore, it is assumed for purposes of this study that the cesium/strontium capsule storage vault will require insulating concrete.

To prevent entry of higher temperature air from one storage vault into another, this study is based on completely isolating the cesium/strontium capsule storage vault from the HLW glass storage vaults. The cesium/strontium capsule storage vault will have its own raised air inlet and an exhaust stack similar to the CSB original design.

6.3.4.2 Hot Cell Ventilation. Storage of cesium/strontium capsules in the CSB will require hot cells for unloading of the shipping cask and consolidation of the capsules into storage overpacks. The hot cells will be served by an independent ventilation system designed in accordance with DOE Order 6430.1A. This system will consist of a supply air system that will condition the outside air as needed and supply this air to the hot cells through HEPA filters. The HEPA filters are provided to prevent the spread of contamination in the unlikely event of a supply air flow reversal. Further analysis may prove that these HEPA filters could be replaced with backdraft dampers. The controlled air flow in the cells will be from clean areas of the hot cells towards areas of increasing contamination. The hot cells will be maintained at a minimum 2 cm water gauge negative pressure with respect to the adjacent areas. The supply air inlets will be located high and the exhaust inlets will be located low in the cells to keep contamination near the cell floor. The exhaust air from the cells will be exhausted through a minimum of two stages of in-place testable HEPA filters and discharged to the atmosphere via an elevated stack. This stack will be provided with stack monitoring systems as required by the DOE Orders, Hanford Plant Standards, and Washington State requirements.

The estimated capacity of the hot cell ventilation system is about 113 m³/min. In the absence of a definitive safety analysis at this time, the exhaust portion of the hot cell ventilation system is assumed to be safety class.

The hot cell operating areas will be served by the existing CSB zone 2 HVAC system. The capacity of this system will be increased by about 57 m³/min to serve the cesium/strontium hot cell operating areas. Since the cesium/strontium hot cell HVAC system is a once-through type, the cooling media will be a chilled water system consisting of air-cooled water chillers, pumps and associated piping. The heating source will be electric.

The base case for this study is the current CSB conceptual design for MCO storage. In this case both MCO storage vaults are cooled by a passive ventilation cooling system consisting of two air intakes and a common exhaust stack. The cesium/strontium capsule storage study is based on storing the capsule overpacks in the third vault and providing an independent passive ventilation cooling system. The additional cost to the current MCO storage conceptual design is the cost of providing an air intake and an exhaust stack for the

cesium/strontium storage vault. For estimating purposes of this study it is assumed that the size of the air intake and the exhaust stack of the cesium/strontium capsule storage vault are same as the sizes for the current CSB design for the storage of MCOs.

The hot-cells and associated operating areas are not required for the storage of MCOs. Therefore, the entire cost of ventilation systems serving the hot cells and the associated chilled water cooling system is in addition to the MCO storage cost estimate. In addition to the ventilation system costs. The exhaust portion of the hot cell ventilation system is assumed to be safety class. Only the exhaust portion of the hot cell exhaust system is of stainless steel construction, the remaining hot cell ventilation system and the operating area ventilation system are of galvanized iron construction.

Detailed thermal analysis of the storage of cesium/strontium capsules is needed to determine the impacts of storing high-heat and low-heat capsules in the same vault, to locate hot spots, to determine if any loading sequence is required to assure that the peak heat load capsules will not exceed their specified temperature limits, and verify the need for insulating concrete.

6.3.4.3 Airborne Effluent Monitoring. The environment within the capsule handling hot cell will be defined as HVAC zone 1. HVAC zone 1 means that there are potentially unsealed sources within the cell. Although time constraints prohibited safety calculations, it is believed that a catastrophic failure of the capsules will cause an offsite impact to the public. Therefore, the cell, which provides the source containment, will be required to be a safety class 1 structure. In addition, the HVAC system, which provides the source confinement, will be designed as a safety class 1 system. The HVAC system includes a dedicated safety class 1 stack that is not provided with the current conceptual design of the CSB. Finally, in accordance with 6430.1A, *General Design Criteria*, 04-06-89, section 1300-9, an airborne effluent monitoring system will be required to monitor this new stack. Section 1300-3.2 requires that the airborne effluent monitoring system also be safety class 1.

The airborne effluent monitoring system continuously monitors effluent from the cesium/strontium capsule handling hot cell. This monitoring system is called a continuous airborne effluent monitor (CAEM). The CAEM contains redundant, safety class 1 isokinetic nozzle arrays, mass flow monitors, flow controllers, pumps, and particulate monitors. This equipment is powered by independent and separated safety class 1E uninterruptable power supplies.

Isokinetic sampling means converting the stack mass flow to a velocity at standard temperature and pressure (STP) and matching that velocity at the inlet of the isokinetic sampling nozzles. There are two isokinetic streams associated with the airborne effluent CAEM. The first isokinetic stream has a beta/gamma continuous air monitor (CAM). The second isokinetic stream consists of a record air sampler.

The particulate monitoring portion of the CAEM consists of redundant safety class 1, beta sensitive continuous air monitors (β CAMs). The β CAMs are provided with a

0.3 micron 99 percent efficient filter that is monitored by a lead shielded, beta sensitive, plastic scintillation detector and a microprocessor based count ratemeter with fail, high and high-high alarms. The plastic scintillation crystal is approximately 5 cm in diameter by 25 mm thick. The detector is provided with a minimum of 5 cm of lead shielding.

The record air sampler is a fixed circular filter approximately 5 cm in diameter, 0.3 micron 99 percent efficient filter contained in a sealed, quick disconnect filter holder. The record air samplers will collect particulate material for later laboratory analysis.

6.3.5 Structural System

Structural impacts resulting from storage of cesium/strontium overpacks in Vault No. 3 of the CSB will be as follows:

The cesium/strontium storage overpacks will weigh about 3.6 MT each. There will be a total of 5 of these overpacks inside of each storage tube. Therefore, the total load inside each tube will be about 18 MT plus impact limiters. Currently each HLW glass canister weighs 4.12 MT each and there are two HLW glass canisters inside each storage tube, with a combined load of 8.24 MT. The load is more than doubled. It is estimated that 4 additional welded threaded studs will be required at the base of each storage tube. The attachment at the top of the storage tube is acceptable as is.

The cesium/strontium overpacks, made from cast iron, are assumed to be able to support themselves stacked on top of each other 5 high. There will be an impact absorber placed between each cesium/strontium overpack. The impact absorber has sufficient strength to support the load of 5 cesium/strontium overpacks. The storage tube therefore need not be stepped and can be one diameter.

Cesium/strontium overpacks will differ in temperature from HLW glass canisters. The outside temperature will be approximately 204 °C. The 204 °C temperature of cesium/strontium overpacks will not affect the material properties of carbon steel significantly and therefore carbon steel for the storage tubes material is still acceptable.

However, because of the hotter temperature of the cesium/strontium overpacks the walls and the underside of the operating deck slab in Vault No. 3 will require insulating concrete to keep structural concrete at an acceptable temperature level during operation. It is assumed that insulating concrete thicknesses in the original CSB design will suffice. Thickness of insulating concrete will be 15 cm on the walls and 25 cm on the underside of the operating deck.

It is also assumed that the cesium/strontium overpack storage vault will be cooled by natural circulation of ambient air and will be isolated from Vaults No. 1 and 2 containing HLW glass canisters. There will be 1-m thick walls added in the intake and exhaust plenums to isolate the HVAC systems of Vaults No. 1 and 2 from Vault No. 3. An additional

exhaust stack and air intake structure will be added for Vault No. 3. The existing exhaust stack and two air intake structures will remain but will be moved south over Vaults No. 1 and 2.

A 51-m diameter, 18-m tall, Zone 1 exhaust stack will also be added. Structural support details are not a major impact. This stack most likely will be supported by the 102-cm Zone 2/3 exhaust stack.

An additional 45-MT capacity crane will be added to service cesium/strontium overpacks. This crane will run on the same rails as the HLW glass canister handling crane. The steel shelter enclosing operating deck of the CSB will be modified to accommodate the 45-MT crane parked 6.1 m northerly measured from the existing north end of the operating shelter. This additional 6.1 m of the operating shelter at and above the rails portion will be over the Control/HVAC building.

On the north end of the Vault No. 1 the HLW glass canister transfer tunnel and corridor will be extended for cesium/strontium overpack handling. The cesium/strontium overpack transfer tunnel is approximately 3-m wide, 21.6-m long, and 7.6-m high (inside dimensions), the corridor is 4.6 m wide. The wall between transfer tunnel and corridor is estimated to be 1.8-m thick, and between the corridor and soil 1.2-m thick.

Above, on the operating deck level the Capsule Handling Hot Cell will be added for inspecting and loading the cesium/strontium capsules into overpacks. Inside dimensions of the hot cell will be 3-m wide, 14.6-m long, and 4.6-m high. The walls of the hot cell are estimated to be 1.8-m thick for shielding.

6.3.6 Special Features

This section provides some additional detail regarding the special features of the storage system and the overpack equipment.

6.3.6.1 Number of Storage Tubes Required. The total number of storage tubes filled by overpacks will be 198, based on a targeted loading of 5 overpacks to a storage tube and no mixing of cesium and strontium in the same tube. Storage Vault No. 3, which will contain 220 storage tubes, would therefore have 22 empty storage tubes after receiving all of the cesium and strontium capsules.

6.3.6.2 Storage Tube Design. The storage tube configuration associated with the original HWVP CSB design was intended to contain three glass-filled overpacks and their impact absorbers. The storage tube inside diameter was to have increased from 69 cm in the lower section housing the bottom two overpacks, to 74 cm in the upper section containing the top overpack. The storage tube was also to have provided vertical support for the upper two overpacks by means of internal mounting supports for the associated impact absorbers.

The storage tube design has been revised slightly for the cesium/strontium overpacks. The inside diameter will now be a uniform 67 cm from top to bottom, and internal mounting supports will be eliminated. The net usable vertical height of each tube will remain 10.7 m.

6.3.6.3 Overpack Arrangement and Support Inside Storage Tubes. An impact absorber will be placed on the floor of the storage tube, below the bottom overpack. A total of four additional impact absorbers will be placed below each of the upper four overpacks. In this way, the five overpacks will not directly contact each other or the floor, even though they are mutually supporting. Thus, the storage tube provides horizontal stabilization but not vertical support for the overpacks. The average height of each of the five impact absorbers is assumed to be 46 cm.

6.3.6.4 Overpack Equipment. The equipment and procedures to emplace storage overpacks containing the cesium/strontium capsules is very similar to those used for emplacement of MCOs containing spent fuel. The handling of Phase II HLW glass canisters may be required to use the same concept. It appears mechanically feasible to use the same handling crane and shielding cask to perform the capsule storage operations. However, the compatibility and the availability of this equipment item cannot be assured for the needs of placing cesium/strontium overpacks into storage. Therefore, an additional handling crane and shielded storage cask is assumed to be required for placing cesium/strontium overpacks into storage concurrently with the movement of HLW glass to and from interim storage. Time and motion studies should be performed in the future to verify this assumption.

Section 6.3.2 describes the operations to unload and package arriving capsules in storage overpacks ready for emplacement in storage tubes in one of the CSB's storage vaults. After the storage overpack is loaded with two capsules, closed, and inspected, it is then transferred underneath a loading port accessible by the storage vault crane. A shielding gate, previously located at the HLW canister unloading port, will be moved to the overpack loading port to provide the necessary shielding for personnel to occupy the storage vault area during transfer operations. A new shielded emplacement cask designed specifically for the capsule overpack will be required for loading of the overpack through the loading port and transfer to its designated storage tube. This cask will be similar in design and operation to the HLW canister shielded transfer cask, but will be smaller in size and weight due to the smaller size of the overpack. A cask design accommodating two or three stacked overpacks could be used if there was a strong desire to reduce the number of handling operations. A second handling crane in the storage vault area designated to handle only cesium/strontium overpacks will run on the same set of rails as the HLW canister handling crane. This second crane will have capacities of 45/9 MT. To permit continued access of the HLW canister handling crane to the HLW canister unloading port, the building runway will have to be lengthened approximately 9.1 m to provide a parking position for the overpack handling crane.

The shielded storage emplacement cask for handling overpacks will be moved over the shielding gate positioned at the overpack loading port. The overpack emplacement crane will then move the shielded cask designated for overpacks onto the transfer gate at the unloading

port. Once secured, the gate valves within the unloading port and shielded cask will be opened, permitting the lifting of a loaded overpack waiting underneath the port into the shielded cask. After transfer gate closure, the cask will be moved to the designated storage tube. Before this transfer, the portable shielding plug cask will be used to remove the plug covering the storage tube. A portable shielding tube gate valve will then be placed over the storage tube with the gate valve in a closed position. It is assumed that the portable shielding plug handling cask and the portable shielding tube gate valve can be shared between the HLW canister and capsule overpack operations. Should future analysis indicate that this is not feasible, a second plug handling cask and gate valve will be necessary.

The shielded emplacement cask with the overpack will be positioned over the storage well and attached to the portable gate valve. The gate valves of both the cask and portable unit will be opened, permitting the lowering of the overpack into the storage tube. Impact limiters will also be lowered before and after placement of the overpack. After all five overpacks and impact limiters have been placed into the storage tube, the portable gate valve will be removed. The portable shielding plug handling cask will then replace the storage tube plug.

In summary, the following mechanical equipment will be added to the CSB for overpack emplacement operations:

Item	Quantity
Overhead handling crane 45/9 MT	1
Shielded transfer cask	1

6.4 TRANSPORTATION METHODS AVAILABLE

The transportation of both cesium and strontium capsules has been successfully accomplished using both government-owned and commercially available shipping casks. There are many casks potentially available to transport cesium and strontium capsules. However, size limitations of the WESF loading area (G Cell), the need to transport a large amount of capsules in each shipment, and the lead time required to certify other casks for capsule transport, limit the choices to two shipping casks.

One cask, the Beneficial Uses Shipping System (BUSS) cask is a high payload (4,000 W) cask certified by both DOE and the NRC to transport cesium and strontium capsules. The cask was fabricated specifically for WESF capsules. The BUSS cask is limited to transporting those cesium and strontium capsule certified as "special form" radioactive material.

The other cask, the General Electric Model 2000 (GE-2000), is currently certified by the NRC for only 600 W and its allowable payload did not specifically include cesium or strontium. However, an amended safety analysis (GE 1994) has been submitted to the NRC and approval for the transport of both cesium and strontium capsules with a payload of 2,000 W is considered imminent.

The use of the GE-2000 cask in WESF requires the fabrication of a capsule "basket" with specific dimensions to accommodate the limited overhead height of WESF's G Cell. The lead time for this basket is expected to be 6 months and cost approximately \$70,000. The cost for purchasing a new GE-2000 cask is approximately \$2 million, with a two year lead time. Both of these factors may limit cask availability based on funding limitations.

6.5 SCHEDULE EVALUATION FOR CAPSULE TRANSPORT TO THE CANISTER STORAGE BUILDING

This section evaluates the major phases for the transfer of capsules from WESF to the CSB. Section 6.5.1 addresses preparation time at WESF for the use of the BUSS and GE-2000 casks. Section 6.5.2 provides the basis for typical shipping campaigns using the BUSS cask or the GE-2000 casks independently and the use of both casks simultaneously. Section 6.5.3 discusses the time required to provide the modifications at the CSB to receive, handle and store the cesium and strontium capsules. Section 6.5.4 evaluates any cesium and strontium storage impacts to K Basin N Fuel emplacement. Section 6.5.5 looks at the impacts of cesium and strontium capsules transport from WESF on B Plant deactivation.

6.5.1 WESF Preparation for Capsule Transfer

A large part of WESF's previous mission was the loading and shipment of the capsules to offsite irradiators. This was accomplished via the use of four different shipping containers. This history demonstrates the versatility and of the building and its staff to prepare the facility for shipping campaigns.

Common elements, regardless of the shipping container used, are operator certifications, training dry-runs, system/equipment tests and management readiness reviews. In 1993 these preparations, performed for the new BUSS cask at WESF, cost approximately \$170,000. The magnitude and duration of these items are somewhat dependant on operations staff experience and staff turnover between the current time period and the initiation of the shipping campaign. For the sake of this estimate, the staff experience levels are assumed to be constant through the initiation of the shipping to the CSB.

The scope of preparing WESF for either the BUSS cask or the GE-2000 cask does not differ significantly, since the casks are of similar configuration. However, the time required to complete the preparation for the BUSS cask is significantly less because of prior use of the BUSS cask in WESF. For example, the BUSS cask operations certification package is

written and approved, while a GE-2000 cask operations certification package would have to be generated. In addition, previous preparedness reviews, dry runs documentation, and lessons learned specific to the BUSS cask can be applied to further reduce the preparation time for the BUSS cask. As mentioned before, the GE-2000 is not expected to be used for the Capsule Recovery Program and therefore, no operational experience for the GE-2000 in WESF will be available.

The required elements to the preparation of WESF can essentially be performed as parallel scheduled tasks. The critical path therefore defined by the task with the longest duration. For the BUSS cask, a review of the augmentation of previous preparedness review for capsule loading (previous review were done for unloading only) is considered the task of longest duration. This task is estimated at four months and includes implementation for any discoveries during the review.

For the GE-2000, development of the operations certification package is considered as the task of longest duration. It is estimated, including development, validation, study time and operator certification at 6 months. Both estimates are based on the actual durations for completing these task for the BUSS cask in 1993.

6.5.2 Time Required to Complete a Single Shipment from WESF to the Canister Storage Building

Actual performance data for BUSS cask operations, performed from May 1994 through June 1995 at both offsite irradiators and WESF indicate that an average of 4 fully staffed 8-h shifts are required for loading and transfer operations. This includes receipt of an empty cask, cask disassembly, cask loading, testing, reassembly and transport to the CSB receiving area.

Operations of the GE-2000 cask does not vary significantly from the BUSS cask. Therefore, the overall duration of loading the GE-2000 is considered to be similar to that required to load the BUSS cask.

In considering the options presented in the following subsections, it must be assumed that savings in outyear surveillance costs at WESF exceed the investments required to accelerate the shipping schedule. This assumption is validated by the life-cycle cost summary provided in the following sections.

6.5.2.1 Shipments Using the BUSS Cask or the GE-2000 Cask Exclusively. Assuming day shift operations only and a four day unloading period at the CSB, transfer of the cesium and strontium capsules would take 6 years using the BUSS cask exclusively. With the smaller payload available with the exclusive use of the GE-2000 cask, the transfer would take 11 years. This is clearly unacceptable from a schedule impact standpoint, but can be used as a "baseline" to evaluate options presented in later sections.

Actual costs preparing WESF, loading and transporting a shipping cask using this "baseline" schedule are estimated to be about \$45,000 per shipment. The unloading costs at the CSB are expected to be similar. These estimates are based on actual costs for loading the BUSS cask at offsite irradiators (OHM 1995) and actual costs required to support BUSS cask unloading operations at WESF in FY 1995.

The loading of the GE-2000 is expected to cost roughly the same as the BUSS cask. However, due to cask availability, a new cask would be required to be purchased at an estimated cost of \$2 million. Taken over the estimated 345 shipments required to transfer the capsule exclusively in the GE-2000, this initial cost does not significantly add to the per shipment cost. In addition, DOE can use the cask to accelerate other shipping programs.

BUSS cask operations conducted on this schedule in 1994 and 1995, allowed for maintenance operations to be conducted while the cask was not at WESF. This resulted in minimum schedule delays (less than two weeks in a year's shipping time) due to equipment operational problems. This is a factor when considering other shipping schedules.

6.5.2.2 Multiple Shift Deployment of Resources. The time required to transfer the capsules from WESF to CSB can be significantly decreased by the deployment of an additional fully staffed shift at WESF. This will decrease the transfer time, using the BUSS cask exclusively, from 6 years to 4.5 years, assuming no additional shifts are added at the CSB to support unloading. With an additional shift at the CSB, the round-trip rate is essentially doubled. Then the exclusive use of the BUSS cask would result in complete transfer of the capsules in 3 years. Similarly, the time required to transfer the capsules using the GE-2000 will be reduced in half to 5.5 years with two shifts at WESF and the CSB.

The disadvantage to this option is the increased labor costs. The effectiveness of matrixing human resources to other tasks during the time when a shipping container is located at the other location is undefined. Therefore, an increased preparation, loading and shipping cost of \$65,000 per shipment is estimated. The deployment of a second shift at the CSB will increase the loading cost similarly to \$65,000/shipment.

6.5.2.3 Use of Both the BUSS and GE-2000 Casks. Without the addition of labor, a reduction of the time required to transfer all the capsules from WESF to the CSB can be accomplished using both the BUSS cask and the GE-2000 cask. This has been accomplished in the past when capsules were shipped from WESF to offsite irradiators. In this case, one of the casks is loaded while the other cask is unloaded. The addition of a GE-2000 cask in this "lead/lag" operations would reduce the transfer time to approximately 4.4 years, at a cask per four shift, single shift shipping schedule.

The disadvantage of this operation is again the initial cost of a GE-2000 cask, if purchased new, of \$2 million. This adds approximately \$25,000 to each of the GE-2000 shipments. Again, this cost can be reduced if other DOE programs can be utilized to take up a portion of the cask costs, for the benefit of future use of the cask.

An additional disadvantage is an increased delay in cask movement due to WESF equipment failures. Previous capsule shipping campaigns experienced little WESF equipment related failures when allowed to conduct maintenance when the cask was not at WESF. In this scenario, a cask will always be at WESF, hence maintenance will have to be deferred, an equipment failures can be expected to increase. Routine maintenance outages will also be required.

6.5.2.4 Transportation Options Comparison and Selection. Table 6-2 provides a list of shipping options examined and associated costs. As mentioned before, the transportation cost must be evaluated relative to the potential cost saving in reduced surveillance at WESF.

A key point in evaluating these transportation options is evaluating the annual benefit of accelerating the removal of the capsules from WESF. The current operating budget of WESF is about \$9 million annually. As discussed in Section 5.0, the budget can be expected to decrease to a minimal cost (\$0.5 to \$1.0 million) after two years of transition. Therefore, an \$8 million per year cost avoidance is assumed.

Table 6-3 uses option 1b (GE-2000 cask, day shift operations) from Table 6-2 as a "baseline" to evaluate the other options. Since option 1b has the longest duration (11 years), it is considered to option with no cost avoidance. The relative net cost avoidance is calculated by determining the cost avoidance at WESF (at \$8 million/year) and deducting the cost of loading and shipping. Because the magnitude of cost differences between options is so large, escalation was not considered significant. Costs common to all options such as (cask maintenance, etc.) were also not considered.

Table 6-3 indicates that the option 3a, the use of the BUSS cask and multiple shifts, is the most advantageous with respect to cost avoidance of the options considered. The risks associated with this option, specifically special form designation of all capsules (and/or the use of the BUSS cask for onsite normal form shipment) should be considered acceptable. Therefore, the use of the BUSS cask exclusively with multiple shifts is the selected option.

As a contingency, the use of the GE-2000 cask with the BUSS cask and multiple shifts (option 4b) may be implemented. Implementation of option 4b provides approximately \$3 million less in cost avoidance, and decreases the transfer time to 2.2 years.

Table 6-2. Comparison of Transportation Options.

Option	Option	Cask(s)	Loading (\$K per shipment)	Unloading (\$K per shipment)	Number of shipments	Cask cost (\$K)	Total (\$K) ²	Time (years)
1a	Day shift only	BUSS Only	45	45	190	0	17,100	6
1b	Day shift only	GE Only	45	45	345	2,000	33,050	11
2a	Two Shifts WESF Only	BUSS Only	65	45	190	0	20,900	4.5
2b	Two Shifts WESF Only	GE Only	65	45	345	2,000	39,950	8.25
3a	Two Shifts at WESF and CSB	BUSS Only	65	65	190	0	24,700	3
3b	Two Shifts at WESF and CSB	GE Only	65	65	345	2,000	46,850	5.5
4a	Lead/Lag Day shift only	BUSS and GE	90	90	123	2,000	24,140	4.4
4b	Lead/Lag Double Shifts at WESF and CSB ¹	BUSS and GE	130	130	123	2,000	33,980	2.2

BUSS = Beneficial Uses Shipping System

CSB = Canister Storage Building

GE = General Electric

WESF = Waste Encapsulation and Storage Facility

¹Costs for items 4a, 4b are for shipment of both a GE-2000 and a BUSS cask.

²Total Cost is for comparison of options listed. These costs do not include WESF preparation, CSB preparation, cask maintenance and other items common to all options. Therefore this total is not a basis for estimating overall transportation costs.

Table 6-3. Comparison of Transportation Options.

Option ^a	Option	Cask(s)	Shipping costs (\$ million) ^a	Time saved (years)	Cost avoidance at WESF (\$ million) ^b	Relative net cost avoidance ^c
1a	Day shift only	BUSS Only	17.1	5	40	22.90
1b	Day shift only	GE Only	33.050	0	0	-33.05
2a	Two shifts WESF Only	BUSS Only	20.900	6.5	52	31.10
2b	Two shifts WESF Only	GE Only	39.950	2.25	18	-21.95
3a	Two shifts at WESF and CSB	BUSS Only	24.700	8	64	39.30
3b	Two shifts at WESF and CSB	GE Only	46.850	5.5	44	-2.85
4a	Lead/lag day shift only	BUSS and GE	24.320	6.6	52.8	28.48
4b	Lead/lag double shifts at WESF and CSB ^a	BUSS and GE	34.240	8.8	70.4	36.16

BUSS = Beneficial Uses Shipping System

CSB = Canister Storage Building

GE = General Electric

WESF = Waste Encapsulation and Storage Building

^aValues taken from Table 6-2

^bAssumes an \$8 million per year reduction in WESF operational costs after the capsules are removed.

^cValues are relative to other cost avoidance numbers and do not represent actual cost avoidance.

6.5.3 Evaluation of Impacts to High-Level Waste Glass Emplacement in the Canister Storage Building

Actual performance data for BUSS cask operations at WESF can be used to forecast the impact to staffing at the CSB. The past performance data show that the average unloading time is 400 workhours to accomplish the following tasks: receive the BUSS Cask, remove the BUSS cask from the truck bed, remove the impact limiter, remove the cover blocks on the hot cell, transfer the BUSS cask into the hot cell, disassemble the BUSS cask, remove the capsule rack, test and inspect the individual capsules for damage, log the capsule identification numbers, install a capsule rack into the BUSS cask, reassemble the BUSS cask, purge and seal the BUSS cask with helium, test the BUSS cask seal, lift the cover blocks on the hot cell, transfer the BUSS cask to the impact limiter, reinstall the impact limiter, and reinstall the BUSS cask on the truck bed. One out of five helium seals fail at WESF and require resealing. The extra time for resealing is included in the average. Approximately 10 percent of the time is for health physics technicians and another ten percent of the time is for supervision. The same tasks and staffing requirements are anticipated to be required at the CSB.

There are additional tasks needed at the CSB, but, are not included in the 400 hours. Storage overpacks will need to be inspected and moved into the hot cells and disassembled. The overpacks are to be filled with two capsules and separated by an inert plug. Identification numbers of the overpacks and capsules will need to be logged. The overpacks will be sealed with helium, seals inspected and tested, and the overpacks surveyed for contamination. The filled overpacks will transported to the CSB storage cell.

The overpack loading and emplacement schedule will coincide with the 3-year capsule receipt schedule. Emplacement of the capsules into the CSB is assumed to occur in between emplacement of the HLW glass canisters and will, therefore, not impact HLW vitrification operations.

7.0 CASE 2B: OVERPACK AT A CANISTER STORAGE BUILDING

Figure 7-1 illustrates Case 2B, which is the overpacking and storage of the overpacked capsules at a HLW CSB. Cask receipt, unloading, capsule handling, and overpack emplacement operations are nearly identical to that described for Case 2A and are not repeated here.

7.1 DISPOSAL OVERPACK

This section discusses the F&Rs of the disposal overpack. These F&Rs are estimated since the actual F&Rs for a disposal overpack would include requirements provided by the DOE-ORCWM. An overpack concept that meets the estimated F&Rs is presented as basis for this study.

7.1.1 Functions and Requirements

Similar to the overpack described for dry storage (Section 6.0), it is assumed that the disposal overpack will function as the primary containment for the cesium and strontium salts while the capsules are stored at the CSB. Other functions of the disposal overpack, however, will be different than the storage overpack for the following reasons:

- The disposal overpack will have less heat generated by the continuing decay of the cesium and strontium isotopes. Whereas the maximum power for the capsules decayed to December 31, 2003, is 212 W for cesium and 508 W for strontium, the maximum wattage for the cesium and strontium capsules decayed to December 31, 2010, is 181 W and 430 W, respectively.

It is assumed that the disposal overpack placed at the Hanford Site is one that the DOE-OCRWM will accept for disposal at the repository (the capsules will not be taken out of the Hanford Site overpack and placed in another overpack at the repository). Therefore, the structural integrity of the capsules after they have been placed in an overpack is less of a concern here than it was for Case 2A. The generally accepted centerline temperature limits are 450 °C for cesium chloride capsules and 850 °C for strontium fluoride capsules (WHC 1992). These limits are imposed to prevent a phase change that would cause an expansion of the encapsulated material and rupture the capsule. Accelerated corrosion of the inner capsule can also occur when the salt/metal interface temperatures reach 400 °C. A salt/metal interface temperatures for cesium capsules is, therefore, set at 350 °C.

- The primary containment for the cesium and strontium will be the overpack--not only during the interim storage period at the Hanford Site, but during the transportation to the repository and, possibly, over the long-term (500 years).

Figure 7-1. Overpacking at a Canister Storage Building.

- The physical features of the overpack (i.e., size and lifting flange) will comply with the canister requirements imposed by the *Waste Acceptance Specifications - Requirements Document* (DOE 1994).

7.1.2 Description of the Overpack

A sketch of the disposal overpack selected for this study is shown in Figures 7-2 and 7-3. The outer wall consists of austenitic stainless steel in compliance with the *Waste Acceptance Specifications - Requirements Document* (DOE 1994). To save the costs of qualifying the package for shipping, the overpack will be made to the HLW canister specifications. A 4.57-m canister will accommodate up to eight capsules. A 3.0-m canister will accommodate 5 capsules. The larger canister is the preferred configuration because it is a more efficient disposal container (see Section 7.4).

To limit the lateral movement, the overpack contains an internal sleeve with fins that extend out to the inner wall of the overpack. Sintered metal spacers in between each of the capsules limit the axial movement of the capsules.

7.1.3 Thermal Analysis

The approach taken for the thermal analysis of the proposed disposal overpack was to assume that the overpack is standing upright in air with natural convection and radiation heat transfer from the vertical sides and top. The bulk air temperature was fixed at 27 °C. The results of the thermal analysis indicate that the salt/metal interface temperature would be maintained at 295 °C for a 181-W cesium capsule and at 425 °C for a 430-W strontium capsule would maintain a salt/metal interface temperature of 374 °C.

7.1.4 Dose Rates

Dose rates for cesium chloride capsules in air and capsules within a disposal overpack are given in Tables 7-1 and 7-2. Table 7-1 lists the dose rates calculated for a single capsules decayed to the years 2010 and 2035 for both maximum and average cesium content. Dose rates calculated at 1 cm represent a surface dose rate. Surrounding the capsule are two shields (metal walls) with a total thickness of either 0.518 cm, 0.564 cm, or 0.691 cm representing the three capsule configurations. Table 7-2 lists the dose rates calculated for the overpack loaded with eight cesium chloride capsules. For this configuration, the cesium chloride was modeled as a cylinder 457.2-cm long with a radius of 2.6 cm. Surrounding this source region is a 0.518 cm (inner plus outer) capsule wall, then a 0.635 cm thick steel tube (the inner sleeve of the overpack) and a 0.953 cm overpack wall. Two additional cases are included in this table showing the dose rates for a total capsule wall thickness of 0.564 cm and 0.691 cm.

Figure 7-2. Disposal Overpack Concept.

Figure 7-3. Disposal Overpack Concept (Exploded View).

Table 7-1. Dose Rates for a Single Capsule.

Case	Decay date	Source (kCi), 1 capsule	Dose location	Dose rate (rem/h)		
				0.518 cm Shield	0.564 cm Shield	0.691 cm Shield
1	2010	Max 37.65	1 cm	1.26 E+06	1.23 E+06	1.17 E+06
2	2010	Avg 27.77	1 cm	9.31 E+05	9.07 E+05	8.62 E+05
3	2010	Max 37.65	1 m	1.02 E+04	1.01 E+04	9.81 E+03
4	2010	Avg 27.77	1 m	7.52 E+03	7.44 E+03	7.23 E+03
5	2035	Max 21.20	1 cm	7.11 E+05	6.92 E+05	6.58 E+05
6	2035	Avg 15.63	1 cm	5.24 E+05	5.10 E+05	4.85 E+05
7	2035	Max 21.20	1 m	5.74 E+03	5.68 E+03	5.52 E+03
8	2035	Avg 15.63	1 m	4.23 E+03	4.19 E+03	4.07 E+03

Source: Schwarz 1995.

Table 7-2. Dose Rates for 8 Capsules In a Disposal Overpack.

Case	Decay date	Source (kCi), 1 capsule	Dose location	Dose rate (rem/h)		
				0.518 cm	0.564 cm	0.691 cm
1	2010	Max 301.20	1 cm	5.89 E+04	5.77 E+04	5.48 E+04
2	2010	Avg 222.16	1 cm	4.35 E+04	4.26 E+04	4.04 E+04
3	2010	Max 301.20	1 m	1.45 E+04	1.43 E+04	1.36 E+04
4	2010	Avg 222.16	1 m	1.07 E+04	1.05 E+04	1.00 E+04
5	2035	Max 169.60	1 cm	3.32 E+04	3.25 E+04	3.08 E+04
6	2035	Avg 125.04	1 cm	2.45 E+04	2.40 E+04	2.27 E+04
7	2035	Max 169.60	1 m	8.18 E+03	8.03 E+03	7.65 E+03
8	2035	Avg 125.04	1 m	6.03 E+03	5.92 E+03	5.65 E+03

Source: Schwarz 1995.

7.2 DISPOSAL OVERPACK PROCUREMENT

This section discusses the data relevant to the procurement of the disposal overpacks.

7.2.1 Quantity

Case 2B (and case 3A) require 246 overpacks for repository disposal. This number was calculated by dividing 1968 capsules by 8 capsules per overpack.

7.2.2 Production/Procurement

The cost of the stainless steel overpack is estimated, on a fabricated per mass basis in 1995 dollars. Stainless steel containers are estimated at \$11.68 per kg (including tax). The estimated weight of an empty HLW canister is 785 kg (Crawford 1995). The additional weight of the inner sleeve/fin results in an total estimated weight of 1,000 kg. Therefore, the total estimated cost of the disposal overpack is \$11,680. This assumes that the most significant element of the cost basis is the bulk materials required to fabricate each overpack. More detailed estimates would include costs associated with capitalization, startup, material, fabrication, quality control, operation, delivery and overhead.

7.3 MODIFICATIONS TO THE CANISTER STORAGE BUILDING

Figure 7-4 (three sheets) illustrates the modifications required at the CSB. The modifications required to overpack capsules for disposal are almost identical to the modifications required to overpack capsules for storage. The capsule handling hot cell will be designed to accommodate the taller 4.57 m canisters. The most significant difference, however, is that the closure of the disposal overpack would require welding whereas the storage overpack is bolted into place. Therefore, Case 2B modifies the closure and inspection station to create an overpack welding and inspection station.

7.3.1 Canister Welding and Inspection Station

The capsule hot cell for Case 2B will have the two modified positions over that provided for Case 2A. The first position is for overpack welding and the second position is used for overpack inspection. The overpack is moved through the hot cell and into these positions with the overpack transfer cart.

Figure 7-4. Modifications to a Canister Storage Building. (Sheet 1 of 3)

Figure 7-4. Modifications to a Canister Storage Building. (Sheet 3 of 3)

The overpacks are welded with a tungsten-inert-gas (TIG) type welder. The welder is designed to work with or without filler material. Jib cranes that service each of the positions within the hot cell move the weld heads onto the overpacks. To locate a welder on an overpack, a pintle or locating provision on the overpack's fill port plug is required. It is assumed that the overpack is welded in one hour.

Selection of the weld inspection technique depends on the overpack's leak tightness criteria. A leakage rate of 1×10^{-7} std cc He/sec, requires a helium mass spectrometer. At less stringent leakage rates, other methods are employed. For the purposes of this study, it is assumed that the mass spectrometer arrangement is used. It is also assumed that the overpack is inspected within one hour.

7.3.2 Number of Storage Tubes Required

Assuming that the working height of each storage tube is at least 10 m, two 4.57-m canisters will fit into each storage tube. Therefore, 123 storage tubes are required to store the 246 disposal overpacks. This represents a little more than half of the 220 tubes envisioned for a single vault at the CSB. For the purposes of this study, however, it is assumed that vaults will be built in increments of 220 tubes to provide contingency storage space or to facilitate heat transfer from the tubes or to distribute the heat in such a way as to facilitate convection currents within the vault.

7.4 OVERPACK DISPOSAL

The transport of vitrified radioactive wastes from the Hanford Site to the repository is currently a repository responsibility. The repository will provide a shipping cask and a means of transport (rail or truck). The Hanford Site's responsibility will be to place the HLW glass into the cask.

The repository disposal fee is published in the *Analysis of the Total System Life-Cycle Cost of the Civilian Radioactive Waste Management Program* (DOE 1995). The fee is based on the estimated repository cost (\$33.1 billion), the defense HLW "fair share" (19.43 percent), the total number of standard (3 m x 61 cm) defense HLW canisters (18,046), and the number of standard Hanford Site canisters (9,860).

The number of total canisters and Hanford Site-produced canisters were taken from the *Integrated Data Base Report for 1993* ORNL (1994). Using these values, Hanford Site's repository disposal fee would be \$3.51 billion if it were to produce 9,860 canisters of HLW. However, the referenced revision of the *Integrated Data Base Report for 1993* incorrectly truncated the number of canisters for the Hanford Site at a value of 9,860 canisters, instead of showing the full amount of estimated production (13,800 standard canisters).

Further evaluation of the fee structure indicates that some of these costs are fixed (development and evaluation and benefits), while others (repository engineering and construction, emplacement operations, caretaker operations, decontamination and decommissioning (D&D), transportation, waste acceptance and Payments Equal to Taxes) are variable, i.e., based on the number of HLW canisters or containers of commercial spent nuclear fuel (SNF). The breakout of fixed and variable costs was derived from DOE/RW (1995, Tables 4-1 thru 4-7) in which comparative life-cycle costs for various processing options and canister sizes were presented. Therefore, the incremental cost for standard (3.0 m x 61 cm) canisters produced at the Hanford Site would be \$198,000.

However, earlier disposal fee estimates in Brandt (1993) showed that there was approximately a 10 to 15 percent increase in the canister-dependent disposal fee when the size of the canister was increased from 3 m to 4.57 m. Applying a 10 percent increase results in a canister-dependent disposal fee of approximately \$220,000 for the longer (4.57 m) canisters.

8.0 CASE 3A: OVERPACK AT THE VITRIFICATION FACILITY

Overpacking operations at the HLW vitrification facility are illustrated in Figure 8-1. The capsules are transferred from WESF (or dry storage) to the facility in a BUSS-like cask where they are overpacked for disposal. The overpacked capsules are then transported to the HLW interim storage facility where they are stored.

8.1 DISPOSAL OVERPACK

The disposal overpack used for Case 3A is the same as that used for Case 2B as described in Section 7.1.

8.2 THROUGHPUT CONSIDERATIONS

This section estimates the throughput requirements for an overpacking operation. The overpacking operation at the vitrification facility must consider the impact on vitrification operations.

8.2.1 Vitrification Down Time

A common assumption about the HLW vitrification process is that it will be down approximately 40 percent of the operating time which means that the melter will idle about 150 days of the year. Further, it is anticipated that the system will be idle during extended periods of time while the front end of the process (waste feed, essential material procurement and regulatory approvals for glass processing) is prepared for the next sustained operation or during an occasional melter change out.

8.2.2 Capsule Overpacking Rate

Since it takes three years of continuous operations to transfer the capsules (Section 6.5), the vitrification facility can expect a shipment of capsules to arrive no more frequently than once a week ($2,000 \text{ capsules}/3 \text{ years}/16 \text{ capsules/shipment} = 42 \text{ shipments/year}$).

Figure 8-1. Overpacking at the Vitrification Facility.

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Therefore, if it is desired to reduce the capsule overpacking to a minimum reasonable time frame--three years--then the capsule packaging operation should be sized to produce 250 overpacks (2,000 capsules) in approximately 450 days. Discounting down time of the overpacking operation from the 450 days (say the overpack operation is available 250/450 or 55 percent of the time), this would be the equivalent of one overpack (eight capsules) per day of production. Thus, it will only take two days of overpacking operation to work off one week of capsule shipments.

The full-scale HLW vitrification facility will be sized to output at least 8,000 canisters over 15 years/0.6 TOE or about 2.5 canisters/day. So, it appears that a minimum capsule overpacking operation of one overpack/day will not require an increase in the throughput required for the HLW glass canister decontamination operation.

8.3 MODIFICATIONS TO THE VITRIFICATION FACILITY

The facility layout for this case is illustrated as Figure 8-2 (2 sheets). The vitrification facility systems that would require modification include the receiving area that is normally used to import empty canisters, a lag storage area for the capsules and a transfer (overpack) hot cell.

8.3.1 Receiving Area

The entry point for the BUSS cask is envisioned to be the same port as that used for empty HLW canisters. The BUSS cask is unloaded as described for Case 2A (Section 6.0) and lowered into a transfer tunnel located at the front end of the canister welding, inspection and loadout operation. Once the cask is lowered into the tunnel, it is then positioned under a hatch where the cart is elevated to mate with the hatch opening. The hatch coverblock is then removed by an overhead crane and set aside. The crane then reaches into the cask and pulls out the capsule basket. The basket is then transported to a lag storage area.

The hatch coverblock is then replaced, the BUSS cask is lowered from the hatch and moved back out to the receiving area using the transport cart.

8.3.2 Lag Storage Area

The lag storage area for the capsule baskets is similar to that provided for case 2A. In this case, lag storage is located adjacent to the canister cooling area. The HVAC provided for the cooling area also services the capsule holding area.

Figure 8-2. Facility Layout for Overpacking at the Vitrification Facility. (Sheet 1 of 2)

Figure 8-2. Facility Layout for Overpacking at the Vitrification Facility. (Sheet 2 of 2)

8.3.3 Transfer (Overpack) Room

From the lag storage area, the capsule baskets are lowered into a dedicated hot cell. This hot cell would be very similar to the capsule handling cell described for Case 2B. As with Case 2B, the capsules are removed from the baskets, one at a time, and placed into the overpack. Unlike Case 2B however, the overpacks are removed from the transfer room without performing the necessary welding and inspection. The overpack is instead placed in the HLW canister line where the overpacks are welded and inspected in the same fashion as HLW canisters.

8.3.4 Summary of Facility Additions

In summary, the following mechanical equipment will be added to the vitrification facility for overpack operations:

Item	Quantity
Canister transfer cart modifications	1
Canister cooling rack modifications	1
Cask container lidding a bolting device	1
Overpack handling PAR	1
Master-slave manipulators	2

In addition to these modifications, the interim storage area (in this case the CSB) must be modified to accommodate the 246 units of overpacked capsules as described for Case 2B.

9.0 CASE 3B: VITRIFICATION OF THE CAPSULE CONTENTS

Case 3B transfers the capsules in a BUSS-like cask to the HLW vitrification facility where the capsule contents are removed and processed into glass. Figure 9-1 illustrates the receipt and transfer of the capsules into the facility.

9.1 PREPARATION OF THE CAPSULE CONTENTS

Figure 9-2 illustrates the preparation of the capsule contents. To prepare the capsule contents for vitrification, they must be removed from their metal containers. The cesium chloride is dissolved in water and the chloride is removed using anion exchange. The strontium fluoride is pulverized to prepare it for blending with other HLW feed. Each of these steps have been demonstrated in previous operations as described in the following sections.

9.1.1 Removal of the Capsule Contents

The WESF was previously used to dismantle 46 cesium capsules from the WESF pool cells and two cesium capsules from Sandia Laboratory, and to process cesium chloride for transfer to B Plant and ultimate transfer to PNNL as CsNO_3 solution in support of the laboratory's fabrication of isotopic heat sources for shipment to the Federal Republic of Germany.

The WESF crew modified an existing pipe cutter to cut through the stainless steel outer capsule. The operations were performed in G Cell. This activity reduced the actual time of cutting and significantly reduced the amount of in-cell solid waste that would have been generated. Because of the very low smearable contamination, the cut up outer capsules were sent to low-level waste burial grounds. After the outer capsules were removed in G Cell by cutting off the welded end caps, the inner capsules were transferred to the D/E Cell and cut into three pieces using a chopsaw. The cut pieces were dumped into 19-L capacity buckets of water. This operation dissolved the cesium chloride leaving the inner capsule material unaffected. The stainless steel inner capsule materials were packaged in 0.21-m³ drums and transported to the B Plant canyon. The drums with the capsule materials were stored at the B Plant canyon until there was enough contaminated equipment for disposal. The drums were then loaded into the drag-off boxes along with the equipment and buried in the 218-E-10 burial grounds in the 200 East Area. The water containing the dissolved cesium chloride was dumped into the sump of D/E Cell, which used steam jets to pump the cesium chloride solution to B Plant for further processing.

Figure 9-1. Vitrification of Cesium/Strontium Capsules.

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VITRIFICATION OF CESIUM/STRONTIUM CAPSULES

Figure 9-2. Preparation of Capsule Contents for Vitrification.

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The same procedure can be used again, although new chopsaws need to be assembled in-plant or procured from an outside vendor. The volume of water needed to process all 1,332 cesium capsules is conservatively estimated to be approximately 4,540 L, resulting in approximately 5,680 L of the processed solution.

Although the same method used to dismantle cesium capsules can be used to cut the strontium outer capsules, the method cannot be used to cut strontium inner capsules. Based on experience at the Oak Ridge National Laboratory (ORNL 1988), strontium fluoride is usually stuck to the inner Hastelloy capsule wall. The laboratory routinely made two longitudinal cuts 180 degrees apart on the Hastelloy capsule using a saw with a 0.13-m disc-type blade, and used a hammer and chisel to break the strontium fluoride salt loose from the capsule walls. This operation broke the salt into several pieces. Using this procedure, the Oak Ridge National Laboratory was able to process about six capsules in three 8-h shifts. The cesium capsule dismantling procedure, therefore, must be modified to include these steps. The chopsaws also require modification to make the longitudinal cuts. The solid waste (inner and outer capsule materials) generated can be disposed of in a manner similar to that of cesium capsules, as described above.

Once the strontium salt is separated from the capsule into several pieces, the pieces can be transferred into a jaw crusher to crush the salt into particles $< 300 \mu\text{m}$ (number 50 sieve) size. Particles $> 300 \mu\text{m}$ (number 50 sieve) size can be recycled through the jaw crusher until the entire batch of capsules is crushed to $< 300 \mu\text{m}$ (number 50 sieve) size particles. Jaw crushers are available commercially for remote operations in a hot cell. The strontium powder will then be transferred to a holding tank as a slurry in water, because strontium fluoride has negligible solubility in water. The constituents of the resulting solutions are given in Table 9-1. It is estimated that the 8,500 kg of shredded metal will result in 100 drums of remote-handled solid waste. The disposal cost for each drum is about \$1,500.

9.1.2 Removal of the Chloride from Cesium Chloride

The removal of the chloride from the cesium chloride solution is illustrated in Figure 9-3. The process uses an anion exchanger such as Dowex² 2x8 to exchange the chloride ion with hydroxide. Hydroxide is the anion of choice because the selectivity of OH^-/Cl^- for Dowex 2x8 is less than one whereas the selectivity of $\text{NO}_3^-/\text{Cl}^-$ is 3.

To avoid any further complication and the introduction of additional chemicals, the anion-exchange bed will not be regenerated. Using vendor information and the compositions given by Table 9-1, a total of 16 columns will be required. After each column has been loaded with chloride, it will be rinsed and disposed in the same manner as the chloride that is removed by the system that scrubs the melter offgas.

²Dowex is a registered tradename of Dow Chemical Company.

Discussions with vendors of Dowex 2x8 (hydroxide form) indicate that the total cost of the ion exchange resin will be approximately \$1.5 million.

9.2 THROUGHPUT REQUIREMENTS

To minimize the cost of continued storage at the WESF, the capsule processing rate should match the optimum rate at which the capsules can be delivered. Since it takes three years of continuous operations to transfer the capsules (Section 6.5), the vitrification facility can expect a shipment of capsules to arrive no more frequently than once a week.

$$2,000 \text{ capsules}/3 \text{ years}/16 \text{ capsules/shipment} = 42 \text{ shipments/year}$$

Based on the previous WESF experience, it will take 5 operators and 5 support personnel about one week (seven days) to process 16 capsules. Additional shifts can be employed to accelerate capsule processing if required.

The cesium hydroxide collection tank has been sized to store the entire volume of the cesium hydroxide plus the water used to rinse the anion exchange column. Similarly, the strontium slurry can be stored indefinitely in its holding tank. The capsule contents could then be blended into the HLW feed or it can be fed to the melter all at once.

9.2.1 Dedicated Campaign

To process all of the prepared capsule contents as a single batch--separate from other HLW feed--the volume of the material has to be large enough to constitute a single batch of melter feed. The size of a batch will be determined by the size of the melter feed adjustment tank (MFAT). The MFAT is where the melter feed is examined, adjusted (if necessary) and passed on the melter feed tank.

There does not appear to be a good reason, however, to process the cesium solution and the strontium slurry separate from the other HLW sludge. The vitrification of a distinctly different feed would require either a new (and costly) glass formulation or it would require the addition of chemicals at the MFAT. Additionally, the HLW melter will probably run as a continuous operation, which means that the melter is not flushed between batches of feed. The presence of another type of glass in the melter means that it will be difficult to keep the glass made from capsule contents separate from the other HLW glass in the melter.

Table 9-1. Cesium and Strontium Capsule Composition and Inventory.*

Cesium capsules (1,332)				Strontium capsules (636)			
Specie	Mass (kg)	wt %	Mol	Specie	Mass (kg)	wt %	Mol
¹³⁷ Cs	547.57	15.678	3,996.87	⁹⁰ Sr	150.22	20.267	1,669.10
Total Cs	3,081.09	88.217	23,183.54	Total Sr	635.96	85.801	7,259.79
Al	0.00	0.000	0.10	Ba		2.411	130.45
Ba	327.00	9.363	2,381.68	Ca		0.567	104.83
Fe	0.00	0.000	0.06	Re		0.146	5.82
K	13.97	0.400	357.20	Fe		0.018	2.33
Mg	0.03	0.000	1.33	Zr		11.020	895.63
Mn	0.01	0.000	0.24	Si		0.009	2.33
Na	70.42	2.016	3,061.70	Mg		0.008	2.33
Pb	0.04	0.001	0.20	Al		0.008	2.33
Rb	0.04	0.001	0.51	Mn		0.012	1.63
Total	3,492.62	100.00	28,986.56	Total		100	8,407.47
NO ₃	1,437.49		23,183.54	F	275.87		14,519.59
316-L stainless steel	6,657.74			316-L stainless steel	1,712.50		
				Hastelloy C	1,630.67		
Total Ci ¹³⁷ Cs =	4.74 E+07			Total Ci ⁹⁰ Sr	2.05 E+07		
(Decayed to January 1, 2000.)				(Decayed to January 1, 2000.)			

*Nankani 1995, Lohman and Poling 1980, and DeWolf 1985.

Figure 9-3. Removal of Chloride From the Cesium Chloride Solution.

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9.2.2 Blend With High-Level Waste Feed

Blending the cesium solution and the strontium slurry into the HLW melter feed stream (as convenient) should have little impact on HLW vitrification operations. A rigorous evaluation of this strategy was performed as part of the evaluation performed for the "CLEAN" option described in the TWRS EIS (Jansen, et al. 1995). The main objective of the CLEAN option is to reduce the volume of HLW sludge. Even though the capsule contents were blended into a reduced volume of sludge, the results of the evaluation showed that there was no increase in the volume of glass product (the volume of the glass was constrained by something other than the cesium and the strontium).

9.3 MODIFICATIONS TO THE VITRIFICATION FACILITY

Figures 9-1 and 9-4 illustrate the areas of the vitrification plant where significant changes would be required to incorporate the capsule vitrification process described above. Table 9-2 summarizes the mechanical equipment that will be added to the vitrification facility for capsule processing operations.

9.3.1 Receiving Area

In this case, the BUSS-like cask enters the vitrification facility at the same port that is used to move solid waste out of the facility. Since these facilities haven't been built yet, they will be designed to also transport the cask to the remotely controlled decontamination cell (shown on the figure as RCDC). As with the other cases, this cell is designed with a hatch that permits the cask to remain on the outside of the cell while a crane removes the hatch cover block, the cask lid and then the capsule basket, in order.

9.3.2 Lag Storage Area

The capsule basket is then transported to a lag storage pit within the remotely controlled decontamination cell similar to the capsule holding area described for options 2A and 2B. This area is sized to hold three of the shipping baskets.

9.3.3 Capsule Cutup Cell

To prevent the unnecessary spread of contamination from capsule dismantling operations, the capsule cutup cell is isolated from the rest of the remotely controlled decontamination cell. The capsules are inserted, one at a time into the cutup cell through an airlock. The capsules are fitted to the chopsaws with remote manipulators. Operators view the operation through glass windows similar to those used at the WESF.

Figure 9-4. Facility Layout for Capsule Vitrification.

Table 9-2. Mechanical Equipment for Capsule Processing Operations.

Item	Identification	Quantity
Lag storage rack	SR-01	1
Disassembly fixture	DS-01	1
Waste transfer table	WB-01	1
Capsule cutup station	DS-01	1
Rinse tank and basket	TK-01	1
Dissolver feed tank w/agitator	TK-02	1
Ion-exchange Clm w/rack	IX-04	3
CsOH collection tank	TK-05	1
Rinse water tank	TK-05	1
CsCl feed pump	P-03	1
Rinse water pump	P-08	1
CsOH transfer pump	P-06	1
Master-slave manipulator	MS-01	3
4.5-MT (5-ton) hot cell crane	CN-01	1
SrF ₂ crushing system/chute	MC-01	1
SrF ₂ slurry mix tank	TK-03	1

9.3.4 Storage Tanks

The cesium chloride solution from the cutup cell is piped to another part of the facility that houses the process tanks and ion exchange columns. The ion exchange columns are designed to allow the periodic replacement of the ion exchange medium. The strontium slurry is stored in its holding tank then piped to the MFAT as becomes available.

10.0 ANALYSIS OF ALTERNATIVES

This section compares each of the disposition alternatives that are detailed in Sections 7.0, 8.0, and 9.0. The following discussion summarizes these options:

- Case 2B is overpack at a CSB
- Case 3A is overpack at a HLW vitrification facility
- Case 3B is vitrification of capsule contents at a HLW vitrification facility.

10.1 COST

Costs for each of the disposition alternatives are presented in Table 10-1. Costs for the no-action alternatives are also given for comparison.

Table 10-1. Cost of Each of the Disposition Alternatives.

Cost (all 1995 dollars)	Disposition alternatives		
	2B	3A	3B
Capital Costs (total engineered cost)			
Processing facility (Note 1)	10	10	22
Interim Storage Facility (Note 2)	8	8	
Total Expense			
Miscellaneous project costs (Note 3)	5	5	6
Processing (Note 4)	4	4	12
Consumables (Note 5)	3	3	2
Interim storage (Note 6)	3	3	
Onsite transportation of canisters (Note 7)	5	25	
Disposal (Note 8)	54	54	
D&D cost (Note 9)	6	6	7
Total Life-Cycle Cost	98	118	49

All costs have been cross-checked with existing cost estimates:

- Transition Projects study on dry storage of capsules (Gerber 1995)
- *Disposition of Cesium and Strontium Capsules Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement* (Nankani 1995)
- *Tank Waste Remediation System Facility Configuration Study* (Boomer et al. 1994)
- *Alternatives for HLW Forms, Containers and Container Processing Systems* (Crawford 1995)
- *Analysis of the Total System Life-Cycle Cost of the Civilian Radioactive Waste Management Program* (DOE 1995).

Each of the notes for this table are discussed below.

Note 1:

- Each capsule processing facility considered is a "blister" on a host facility
- Capsule vitrification includes capsule disassembly and removal of chloride from the CsCl compound through anion exchange.

Note 2:

- Interim storage for each case is a "blister" to a CSB for immobilized HLW

Note 3:

- Miscellaneous project costs include development costs, safety analysis reports, management, startup, compliance activities, etc

Note 4:

- Processing cost is the labor required to manage, operate, and maintain either the overpack process or the vitrification process
- Includes effluent treatment and disposal costs

Note 5:

- Consumables are overpack canisters or chemicals and ion exchange resin

- Overpack canisters for Case 2A is designed to dissipate large amounts of heat (solid ductile cast iron)
- The overpack for Cases 2B and 3A are modified 4.57-m HLW glass canisters
- Assume that all but 4 strontium canisters eventually come back for disposal, for a total of 636
- 1,968 total, intact capsules (1,332 cesium capsules plus 636 strontium capsules)
- 1,968 capsules, 8 capsules/canister = 246 canisters
- Canister cost is \$11,680 per unit
- Total cost of the canisters is \$2.9 million (246 canisters times \$11,680)

Note 6:

- The interim storage operation for Cases 2B and 3A is the management, operation and maintenance of a blister on a CSB
- If the contents of the capsules are removed and the salts are blended with other HLW streams and vitrified, the incremental number of canisters is negligible.

Note 7:

- Function 4.2.3.6, Prepare cesium/strontium Capsules for Disposal, assumes that the capsules are intact and that Transition Projects will deliver the capsules to the capsule preparation facility
- Transportation of canisters is estimated to be \$50,000 to load and \$50,000 to unload for a total cost of \$100,000 per canister (based on WESF loading and unloading of BUSS casks at \$130,000 each trip)

Note 8:

- Current repository cost estimates (\$33.1 billion) and DOE's "fair share" allocation (19.43 percent), as documented in DOE/RW-0479 (DOE 1995), results in an incremental disposal cost of approximately \$220,000 for 4.57-m canisters and \$198,000 for 3-m canisters.
- 246 canisters times \$220,000/canister = \$54 million

- If the standard 3-m canister is used, only 5 capsules per canister can be accommodated, increasing the number of canisters requiring disposal to 394, at a disposal cost of \$97 million.

Note 9:

- D&D costs are estimated at 30 percent of capital costs

For comparison, the estimated cost of a standalone facility, as documented in the *TWRS Multi-Year Program Plan* (Wojtasek 1995), is \$150 million.

Figure 10-1 highlights the most significant cost variables for the two overpacking (capsule disposition) options considered. The baseline for the chart is overpacking at the HLW vitrification facility as described in Section 8.0. Specifically, and in order of increasing significance:

- The cost of shipping the overpacks from the HLW vitrification facility to a canister storage building can be eliminated by overpacking at a canister storage building. This would save as much as \$25 million.
- If a retrofit of a canister storage building is required to store the overpacks (i.e. a fourth vault), then the capital cost of the interim storage facility will be \$29 million instead of the \$8 million required to finish a third vault (Calmus 1996).
- If the repository disposal fee for each HLW canister is \$356,000 (DOE 1995) instead of \$220,000, the total disposal cost will be \$88 million.

Figure 10-1. Significant Cost Variables for Overpack Options.

Figure 10-2 highlights the most significant cost differences between the overpacking and the vitrification options described in Section 9.0. The baseline for the chart is overpacking at the HLW vitrification facility as described in Section 8.0. It shows that the higher costs of vitrification are more than offset by the savings realized by eliminating the storage and disposal of overpacks. Specifically, and in order of increasing significance:

- The D&D costs associated with the vitrification option are more than the costs of D&D for an overpacking facility. The one million dollar (\$1 million) difference between the two cases is consistent with the estimated cost for the deactivation of WESF as described in Section 6.0.
- The vitrification alternative eliminates \$3 million in expenditures associated with the monitoring of overpacks to the year 2028.
- The expense associated with the vitrification of capsule contents will cost about \$8 million more than the expense associated with the overpacking operation.
- The capital associated with a simple system to prepare the capsules for vitrification is estimated to be \$22 million. A more elaborate processing of the halides as described in the *Extensive Separations Pretreatment Alternative Engineering Data Package for the TWRS EIS* (Jansen, et al. 1995) would cost an estimated \$35 million. Therefore, there could be as much as a \$25 million cost difference between the capital required to build a capsule dismantling facility and the capital required to build an overpacking facility.

Figure 10-2. Significant Cost Differences Between Capsule Disposition Options.

So, as much as an additional \$37 million would be required to vitrify the capsule salts. Alternatively, the vitrification alternative could save:

- \$25 million in onsite transportation costs
- \$29 million in interim storage facility costs (CSB retrofit)
- \$88 million in DOE's share of the repository costs.

The net difference in hard dollar savings if the vitrification option is selected would be over \$100 million. This calculation does not include any incremental costs of qualifying an alternative waste form (halides) for repository disposal assuming that the repository would accept overpacked capsules. Input from the repository on the halide acceptability issue is still pending.

10.2 SCHEDULE

All three TWRS alternatives can be structured to meet the current Storage and Disposal Project schedule. If one of the overpack options is chosen, there is a risk that OCRWM may determine the halide waste form to be unacceptable in the future.

10.3 OPERABILITY

The vitrification alternative, Case 3B, is inherently more complex than the overpack alternatives. The addition of the cesium hydroxide solution and the strontium slurry to the melter feed adjustment tank will create some additional dynamics within the vitrification system. The capsule processing for vitrification adds an increment of diversity of systems and equipment albeit small compared to the rest of the vitrification facility. The concepts presented for Case 3B, however, use simple, mature technologies and equipment, rather than novel and unique technologies and equipment for which there is little operating experience.

10.4 MAINTAINABILITY

The maintainability of a capsule overpack system is judged to be greater than that of the vitrification system as assessed by evaluating the complexity, reliability and repairability of the associated equipment and components. The repairability of the vitrification equipment is heavily influenced by the high degree of contamination expected for the operation.

10.5 SAFETY

The onsite hazards associated with the vitrification operation are offset, somewhat by the offsite hazards associated with the overpack alternatives.

With regard to onsite safety, the vitrification of capsule contents is an inherently messy, albeit short-term, operation. The vitrification alternative would create both solid and liquid secondary wastes. The metallic capsule container would be separated from their contents and shredded for size reduction, thereby creating about 100 drums of remote-handled waste for burial. Removing chloride from the cesium salt would create approximately 115 drums of chloride-loaded ion-exchange resin that would require disposal as mixed waste. The decontamination of the capsule disassembly equipment and cell would create liquid wastes. In contrast, an overpacking operation would be expected to create very little secondary wastes.

With regard to offsite safety, the glass made with the vitrification alternative is much more stable than the current halide (salt) form of cesium and strontium. The corrosion of the capsules due to their contact with the halide contents is highly dependent on the types and quantities of impurities that reside within the capsules. There is insufficient knowledge about these impurities, however, to obtain a definitive determination of how long the capsules will remain intact in an interim storage environment and after disposal in the geologic repository.

10.6 ENVIRONMENTAL ACCEPTABILITY

The glass waste form from the vitrification alternative is environmentally more acceptable than the halide waste form. It is assumed that the capsule residue and the chloride taken from the vitrification process will be treated for disposal in accordance with the prevailing treatment standards.

The liquid effluents from the vitrification alternative are much more significant to the environment than the liquid effluents from an overpacking operation.

The gaseous effluents from the vitrification alternative are a significant risk to the environment compared to the minimal gaseous effluents from an overpacking operation.

The overpacking operation will probably increase the permitting requirements for the host facility and certainly for the interim storage facility. The vitrification option, however, will probably have very little impact to the permit obtained for the vitrification facility.

10.7 TECHNICAL MATURITY

The processes that would be used to implement the overpacking alternatives and the vitrification alternative all use mature technology. The acceptability of halides at the geologic repository, however, introduces a high degree of regulatory uncertainty.

10.8 COMPLEXITY OF INTERFACES

The inputs (and their associated requirements) to the capsule disposition function are the same for each of the alternatives considered. The proposed disposal of halide salts at the repository, has introduced a significant amount of complexity in the Hanford-repository interface. The vitrification option would simplify this interface considerably since the glass product represents a standard waste form.

10.9 SUMMARY

Table 10-2 presents a summary of the discussion of the TWRS alternatives.

Table 10-2. Alternatives by Performance Measure Matrix.

Performance measure	Alternatives		
	2B Overpack and store at a high-level waste Canister Storage Building	3A Overpack at the High-Level Waste Vitrification Facility and store at a Canister Storage Building	3B Vitrify capsule contents at the High-Level Waste Vitrification Facility
Total capital cost	18	18	22
Total expense cost	80	100	27
Total life-cycle cost (in 1995 \$ millions)	98	118	49
Schedule	The capsules can be overpacked within three years during the operation of a full-scale canister storage building	The capsules can be overpacked within three years during the operation of a full-scale vitrification facility	The capsule contents can be vitrified within three years during the operation of a full-scale vitrification facility
Operability	An overpacking operation would be relatively simple	An overpacking operation would be relatively simple	A vitrification operation is more complex than overpacking but it does not require complicated machinery
Maintainability			The high degree of contamination would make it more difficult to repair equipment
Onsite safety	Overpack at the interim storage location eliminates a transportation step		Requires opening of capsules and generating secondary wastes
Offsite safety	The halide waste form is not as stable as the glass waste form. (The repository has yet to respond to Hanford's request for a determination of halides as an acceptable waste form.)	The halide waste form is not as stable as the glass waste form	
Environmental acceptability	Fewer effluents than vitrification; offsite acceptability is uncertain	Fewer effluents than vitrification; offsite acceptability is uncertain	Glass waste form is more acceptable than salt waste form
Technical maturity	Regulatory uncertainty with regard to the halide waste form and estimates of capsule corrosion	Regulatory uncertainty with regard to the halide waste form and estimates of capsule corrosion	Uses proven technology
Complexity of interfaces	Requires complicated interface with the repository to determine if halides will be acceptable and to determine if an overpack is required	Requires complicated interface with the repository to determine if halides will be acceptable and to determine if an overpack is required	Produces a standard high-level waste form; no additional Hanford-repository interface required

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APPENDIX A

LIMITING SALT/METAL INTERFACE TEMPERATURE ESTIMATES
FOR STORAGE OF CESIUM AND STRONTIUM CAPSULES

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Westinghouse
Hanford Company

Internal
Memo

From: Materials and Corrosion Engineering 74A10-95-RPA-024
Phone: 373-0785 R1-30
Date: July 11, 1995
Subject: LIMITING SALT/METAL INTERFACE TEMPERATURE ESTIMATES FOR STORAGE OF
CESIUM AND STRONTIUM CAPSULES IN THE CANISTER STORAGE BUILDING

To: J. A. O'Brien S6-81

cc: R. D. Claghorn H5-49 R. L. Gibby H5-27
G. L. Dunford S7-81 P. C. Ohl R1-30
L. R. Eisenstatt H5-27 E. H. Randklev H5-27
RPA/File/LB

The attached report documents the limiting salt/metal interface temperature estimates for cesium and strontium capsules for dry storage in a canister storage building. The report includes the corrosion data generated at the Hanford Site on these capsules along with the assumptions made in estimating the temperatures below which the metal/salt interface should be maintained for 40-year and 80-year dry storage in the canister storage building. Some concluding remarks and recommendations are also included in the report.

Based on the analysis described in the report, the limiting metal/salt interface temperatures are 317 and 258°C for CsCl capsules and 540 and 453°C for SrF₂ capsules respectively for 40-year and 80-year dry storage.

Should you have any questions or need additional assistance, please do not hesitate to call me on 373-0785.

R. P. Anantatmula

R. P. Anantatmula
Fellow Engineer

Attachment

CONCURRENCE:

J. R. Divine
J. R. Divine
ChemMet Ltd PC

Date: 11 July 95

Attachment

**LIMITING METAL/SALT INTERFACE TEMPERATURE ESTIMATES
FOR
DRY STORAGE OF CESIUM AND STRONTIUM CAPSULES**

By

R. P. Anantatmula

**Westinghouse Hanford Company
Richland, Washington**

LIMITING METAL/SALT INTERFACE TEMPERATURE ESTIMATES
FOR
DRY STORAGE OF CESIUM AND STRONTIUM CAPSULES

1.0 INTRODUCTION

This report has been prepared in support of a project evaluating the feasibility of dry storage of radioactive CsCl and SrF₂ capsules in a canister storage building at the Hanford Site. The present report calculates the limiting metal/salt interface temperatures below which the CsCl and SrF₂ capsules should be maintained for 40-yr and 80-yr dry storage. The limiting temperatures were computed on the basis of corrosion data obtained primarily at Hanford on the cladding materials used to encapsulate the salts (Bryan, 1989; Fullam, 1981).

2.0 CORROSION DATA

2.1 CsCl CAPSULES

These capsules were doubly encapsulated in capsules fabricated from AISI Type 316L stainless steel (316L) material. Three different capsule wall thicknesses were used during the construction of these capsules. The minimum wall thickness is 0.109".

The CsCl/316L compatibility experiments were performed at the Pacific Northwest Laboratory (PNL) (Bryan, 1989) with radioactive ¹³⁷CsCl generated at the Waste Encapsulation and Storage Facility (WESF). The experiments were performed for up to 5.9 years in prototypic WESF-production capsules prepared according to the U.S. Department of Energy (DOE) requirements in existence at the time. Bryan dropped the 1-yr and 5.9-yr data and calculated corrosion rates at the average temperatures of 451, 432, and 419°C by linear extrapolation. For additional experimental details, the reader is referred to (Bryan, 1989).

For the present report, the corrosion rate at the average temperature of 374°C was calculated from Bryan's data by taking the average of the maximum and minimum corrosion rates. The depth of attack for this lower temperature group of specimens ranged from 20 to 50 microns (μm), while the corresponding exposure time ranged from 2,208 hours to 51,432 hours. The maximum corrosion rate and maximum depth of attack were observed in a specimen exposed to 4,392 hours and the minimum corrosion rate was recorded for the specimen with the maximum exposure time. As Bryan pointed out in his report, the depth of attack is not directly related to the exposure time or temperature (for this low temperature group). He attributed this to the presence of different amounts of impurities in the salt in contact with the different specimens and expected the corrosion to stop once

the impurities are consumed by reaction with the cladding. It is also apparent that the rate of attack is generally quite low at lower temperatures, which is consistent with the hypothesis that corrosion is a thermally activated diffusion-controlled process.

Corrosion data from two WESF capsules destructively examined after 5 years in Sandia Irradiator for Dried Sewage Solids (Sasmor et al., 1988) were also considered for the temperature estimates in order to describe the relationship between corrosion rate and temperature more accurately at the lower temperatures. Recent thermal analysis calculations (Beaver, 1995a) predict a metal/salt interface temperature of 158°C for the maximum inventory CsCl capsule decayed to 12/31/2000 for a canister configuration with 8 such capsules arranged vertically end-on-end.

The corrosion data for the CsCl capsules are given in Table 1.

TABLE 1
CORROSION DATA OF 316L EXPOSED TO WESF GRADE CsCl

Temperature (°C)	Corrosion Rate ($\mu\text{m/yr}$)
451 ^a	137
432 ^a	116
419 ^a	99
374 ^b	55
170 ^c	5

a - Data from Bryan, 1989

b - Calculated from the data of Bryan, 1989

c - Data from Sasmor et al., 1988

2.2 SrF₂ CAPSULES

Similar to the CsCl capsules, these capsules were also doubly encapsulated. However, the inner capsule in contact with the ⁹⁰SrF₂ is Hastelloy C-276. The inner capsule wall thickness for the SrF₂ capsules is 0.12".

The ⁹⁰SrF₂/Hastelloy C-276 compatibility experiments were performed at PNL (Fullam, 1981) at 600°, 800°, and 1000°C for up to 30,000 hours. At all three temperatures, the maximum depth of attack was observed at the maximum exposure time. In some cases, for intermediate exposure times, the depth of attack was more for shorter times than longer times of exposure. Similar to the CsCl case, Fullam attributed this to the differences in the impurity content of the salt for different tests and expected the

corrosion to stop once the impurities are consumed by reaction with the cladding. The corrosion data for the SrF_2 capsules are given in Table 2.

The data in Table 2 were obtained by Fullam for a surface area of capsule (S) to volume of $\text{WESF } ^{90}\text{SrF}_2$ (V) ratio (S/V) of 4.5 cm^{-1} . The actual S/V value for the WESF capsules is 0.9 cm^{-1} . Performing the experiments at the lower S/V ratio would have required a larger quantity of $^{90}\text{SrF}_2$ and, therefore, Fullam opted to do the experiments at the higher ratio. However, Fullam

TABLE 2

CORROSION DATA OF HASTELLOY C-276 EXPOSED TO $^{90}\text{SrF}_2$

Temperature ($^{\circ}\text{C}$)	Maximum Attack Depth (μm)	Corrosion Rate ($\mu\text{m/yr}$)
600	225	66
800	350	102
1000	875	383

performed some experiments with inert SrF_2 at a S/V value of 0.9 cm^{-1} as well as 4.5 cm^{-1} . These experiments at 600°C (up to 20,000 hours) indicated an increase in corrosion rate by a factor of 1.5 at the lower S/V ratio.

3.0 MODEL AND ASSUMPTIONS

3.1 MODEL

The data in Tables 1 and 2 were fitted to an Arrhenius equation since the corrosion process is expected to be thermally activated and diffusion controlled. The following equation was used in the calculations.

$$Y = A \text{ EXP } (-Q/RT) \quad (1)$$

where

- Y = corrosion rate in $\mu\text{m/yr}$
- A = constant
- Q = activation energy (cal/mole) for corrosion
- R = universal gas constant (cal/mole/ $^{\circ}\text{K}$)
- T = temperature ($^{\circ}\text{K}$)

A computer program for least squares exponential curve fitting was used to compute the values for the parameters A, Q and r^2 , where r^2 is the coefficient of determination. A value of r^2 close to 1 indicates that the fit is very good.

Next, equation (1) was used to determine the temperature in $^{\circ}\text{C}$ below which the metal/salt interface of the CsCl and SrF_2

capsules should be maintained for a) 40-yr and b) 80-yr dry storage in a canister storage building.

3.2 ASSUMPTIONS

For both CsCl and SrF₂ capsules currently stored in WESF water basins, the inner capsule wall corrosion at the salt/metal interface is assumed to be 0 $\mu\text{m}/\text{yr}$ prior to emplacement of capsules in dry storage. This assumption is supported by the results obtained from the destructive examination of capsules removed from the WESF water basins (Bryan, 1989). The amount of corrosion observed in the water storage capsules (storage period ranging from 0.4 to 8.9 yrs) was not much different from that observed immediately after the capsule loading operations.

The limiting temperatures for 40-yr and 80-yr dry storage were calculated assuming the metal/salt interface temperature remains constant throughout the storage period. This is an extremely conservative assumption since the metal/salt interface temperatures are expected to decrease with time due to decay of radionuclides.

3.2.1 CsCl Capsules

The temperature estimates for these capsules were made assuming the inner capsule wall is totally corroded through. In addition, credit was taken for only 55% of the outer wall thickness as a corrosion barrier. This assumption is based on the premise that the outer capsule endcap welds were required to be only 55% penetration welds. Additional conservatism was also incorporated into the calculations with the assumption that all the capsules were fabricated with the minimum thickness wall.

3.2.2 SrF₂ Capsules

The temperature estimates for these capsules were made by considering 100% of the inner capsule wall as a corrosion barrier, while taking no credit to the outer capsule wall.

4.0 RESULTS

4.1 CsCl CAPSULE RESULTS

The computer program used for least squares exponential curve fitting yielded the following values for equation (1) parameters for the CsCl capsules.

$$\begin{aligned} A &= 21000 \\ Q &= 7400 \text{ cal/mole} \\ \text{and } r^2 &= 0.99 \end{aligned}$$

The value of $r^2 = 0.99$ indicates the fit is good.

The limiting temperatures calculated from equation (1) are 317°C and 253°C for 40-yr and 80-yr dry storage respectively for these capsules.

4.2 SrF₂ CAPSULE RESULTS

The following parameters were calculated by the computer program fitting the SrF₂ capsule corrosion data with equation (1).

$$\begin{aligned} A &= 12,000 \\ Q &= 9300 \text{ cal/mole} \\ \text{and } r^2 &= 0.85 \end{aligned}$$

The value of $r^2 = 0.85$ indicates the fit is not as good as that for the CsCl case.

To retain conservatism in these calculations and to account for the smaller S/V ratio of the WESF capsules, the corrosion rate value obtained from the above equation was multiplied by a factor of 2. Application of equation (1) yielded limiting Hastelloy C-276/SrF₂ interface temperatures of 540°C and 453°C for 40-yr and 80-yr storage respectively in the canister storage building.

5.0 CONCLUDING REMARKS

As pointed out earlier in the report, the limiting temperatures for dry storage were calculated assuming constant temperature throughout the storage period. To demonstrate how the corrosion rate decreases with storage time, the temperatures calculated by Beaver (1995a,b) for decay years between 2000 (12/31/2000) and 2035 (12/31/2035) were first plotted and extrapolated to year 2040. Then the temperatures from the plot were plugged into equation (1) to compute the corrosion rates for both CsCl and SrF₂ capsules for years 2020 and 2040. The corrosion rates are 18 $\mu\text{m/yr}$ and 6 $\mu\text{m/yr}$ for SrF₂, and 1.6 $\mu\text{m/yr}$ and 0.7 $\mu\text{m/yr}$ for CsCl for years 2020 and 2040 respectively.

Furthermore, both Bryan and Fullam indicate that corrosion of the capsule wall is caused by the impurities contained in the salts. Therefore, once the impurities are totally consumed, the corrosion of the capsule wall should reach negligible levels.

The thermal analysis results (Beaver, 1995a,b) mentioned in this report are for a canister configuration with 3 capsules arranged end-on-end inside a 27" 316L canister. The package also includes a 3.5" diameter 316L aligning tube to position the capsules in the center of the canister. Beaver made the temperature estimates assuming the air surrounding the canister is at 80°F temperature. It should be noted that the metal/salt interface temperature could be higher than calculated by Beaver if a less conservative canister design is used or if the ambient air temperature is higher than 80°F. Ambient air temperature is

expected to be higher especially for repository storage because of areal heating by other canisters and lower heat losses.

Based on the data described in this report, it may be concluded that dry storage of the CsCl and SrF₂ capsules in the canister storage building is feasible. However, caution must be exercised in selecting the canister design and providing ventilation to the canister storage building. It is also recommended to conduct cladding compatibility tests on these capsules (especially SrF₂) at lower temperatures to add additional confidence to the present estimates.

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