ENGINEERING CHANGE NOTICE

1. ECN 645045

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental [] Direct Revision [X] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	A. L. Pajunen, R3-86, 376-7115	[] Yes [X] No	11/25/97
	6. Project Title/No./Work Order No.	7. Bldg./Sys./Fac. No.	8. Approval Designator
	SNF Project	142-K	SQ
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.)	10. Related ECN No(s).	11. Related PO No.
	WHC-SD-SNF-OCD-001, Rev. 0	N/A	N/A

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[] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	N/A	N/A Design Authority/Cog. Engineer Signature & Date	N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? [X] Yes [] No

Complete rewrite and title change. Revision 0 of this document required DOE approval as a milestone committment. Revision 1 approval designatin is S,Q.

14a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

14b. Justification Details

As of this date the current SNF Product Specification may be found in HNF-SD-SNF-OCD-001, Rev. 1

15. Distribution (include name, MSIN, and no. of copies)

See Attached Distribution Sheet

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1. ECN (use no. from pg. 1): 645045

16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
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[X] No	Savings	[] $	Savings	[] $	Delay	[]

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision

21. Approvals

	Signature	Date		Signature	Date
Design Authority	See "Other"		Design Agent		
Cog. Eng.	A. L. Pajunen (signed)	1/29/98	PE		
Cog. Mgr.	J. R. Frederickson (signed)	1/29/98	QA		
QA	D. W. Smith (signed)	1/30/98	Safety		
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Environ.			Environ.		
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CVD DA	J. J. Irwin (signed)	12/12/97	Signature or a Control Number that tracks the Approval Signature		
HCS DA	C. R. Miska (signed)	1/30/98			
Safety	R. P. Omberg (signed)	1/30/98	ADDITIONAL		
	J. P. Sederburg (signed)	12-10-97			

SPENT NUCLEAR FUEL PROJECT PRODUCT SPECIFICATION

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U.S. Department of Energy Contract DE-AC06-96RL13200

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Abstract: This document establishes the limits and controls for the significant parameters that could potentially affect the safety and/or quality of the Spent Nuclear Fuel (SNF) packaged for processing, transport, and storage. The product specifications in this document cover the SNF packaged in Multi-Canister Overpacks to be transported throughout the SNF Project.

***ARES Corporation, Richland, WA 99352**

Kara L Broz 1/30/98
Release Approval Date

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SPENT NUCLEAR FUEL PROJECT PRODUCT SPECIFICATION

November 25, 1997

Prepared for the U.S. Department of Energy Office of Environmental Restoration and Waste Management

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1.0 INTRODUCTION

Product specifications are limits and controls established for each significant parameter that potentially affects safety and/or quality of the Spent Nuclear Fuel (SNF) packaged for transport to dry storage. The product specifications in this document cover the SNF packaged in Multi-Canister Overpacks (MCOs) to be transported throughout the SNF Project.

The SNF includes N Reactor fuel and single-pass reactor fuel. The FRS removes the SNF from the existing storage canisters, cleans it, and places it into baskets. The MCO loading system places the baskets into MCO/Cask assembly packages. These packages are then transferred to the Cold Vacuum Drying (CVD) Facility. After drying at the CVD Facility, the MCO cask packages are transferred to the Canister Storage Building (CSB), where the MCOs are removed from the casks, staged, inspected, sealed (by welding), and stored until a suitable permanent disposal option is implemented. The key criteria necessary to achieve these goals are documented in this specification.

2.0 SPECIFICATIONS

Product specifications for the Spent Nuclear Fuel (SNF), Multi-Canister Overpack (MCO), and Cask are provided to insure that packages leaving the Fuel Retrieval System (FRS), Cask loading station, CVD Facility, and Weld Station for transportation, processing, and storage activities are safe and of high quality. The specifications in this document are intended to be in addition to the individual sub-project performance specifications.

2.1 Fuel Retrieval And Cleaning

2.1.1 Fuel Surface Area Remaining Uncleaned	< 20% (This value may change pending evaluation of $Al(OH)_3$ removal requirements)
2.1.2 Scraploading	
2.1.2.1 Material With dimension < ¼ in	Limited to that clinging to fuel elements after cleaning
2.1.2.2 Scrap < 1 inch and ≥ ¼ inch	Placed in fine area of scrap basket
2.1.2.3 Scrap > 1 inch	Placed in scrap basket
2.1.3 Fuel Loading	Fuel and fuel pieces must remain in sockets
2.1.4 Fuel queuing	Fuel basket queue storage < 30 days

2.2 MCO Loading System

2.2.1 Number of baskets of scrap	≤ 1
2.2.2 Position of basket of scrap	Top basket position
2.2.3 MCO Sealing	≤ 0.006 in. particle size on seal

2.3 Cask Loading and Transport System

2.3.1 MCO Cask Package Backfill Gas	99.9% Helium
2.3.2 MCO Cask Package Pressure	13.8 kPa to 20.7 kPa gage at ambient temperature
2.3.3 Cask water fill level	Within 10 cm (4 inches) of bottom of shield plug (both MCO and Cask)
2.3.4 Transport Between K Basins and CVD	< 24 hours

2.4 Cold Vacuum Drying

2.4.1 MCO Free Water Inventory	≤ 200 g
2.4.2 MCO Backfill Gas	
2.4.2.1 Gas	99.9% Helium
2.4.2.2 MCO Backfill Gas Temperature	25°C to 35°C, when backfill pressure is measured
2.4.2.3 Backfill Pressure	40 kPa to 60 kPa, gage
2.4.2.4 MCO Integrated Leakage Rate	< 10^{-4} std cc/sec*
2.4.3 Cask Backfill Gas	
2.4.3.1 Backfill gas	Air with ≤ 1 vol% water vapor
2.4.3.2 Backfill temperature	Ambient
2.4.3.3 Backfill pressure	Ambient
2.4.4 Cask Shipping Temperature	≤ 25°C
2.4.5 Halogenated and/or organic Compounds	None added by process

2.5 Cask Transport to CSB

2.5.1 Transport Between CVD and CSB	< 5 days*

2.6 Canister Storage Building Systems

2.6.1 MCO staging at CSB	< 15 months*
2.6.2 Leakage rate after welding	< 10^{-7} std cc/sec
2.6.3 Sealed storage condition	
2.6.3.1 MCO maximum internal pressure	165 psia
2.6.3.2 MCO Gas Temperature	≤ 157°C
2.6.3.3 Water and Gas Inventory in MCO	Controlled by process systems and bounding analyses. See Table 2-1 for contribution summary.

2.7 MCO Interim Storage — ≤ 40 years

* Activities are under way to reduce the mechanical leakage criteria to 10^{-5} std cc/sec. This modification will increase the allowable transport and staging times.

Table 2-1 Allocation of MCO Pressure Contributions

Pressure Contributor			Comment
2.6.3.3.1 Total Gas at 165 psia and 157°C		159 gmol	
2.6.3.3.2 Contingency		15.9 gmol	
2.6.3.3.3 MCO Backfill Gas	≤	32.7 gmol	Controlled by 2.4.2
2.6.3.3.4 Noble Gas Release	≤	0.1 gmol	Bounding Analysis
2.6.3.3.5 Helium Delay Product	≤	0.1 gmol	Bounding Analysis
2.6.3.3.6 Oxygen	≤	5.7 gmol	Bounding Analysis
2.6.3.3.7 Water and Hydrogen	≤	104.5 gmol	By Difference
2.6.3.4 Allocation of Bound and Free Water			
Cladding Film, Scrap		420 g	Bounding Analysis
Cladding Film, Fuel		456 g	Controlled by 2.1.1
Oxide Film, Scrap		33 g	Bounding Analysis
Oxide Film, Fuel		39 g	Bounding Analysis
Scrap Particulate		410 g	Bounding Analysis
Fuel Particulate		240 g	Bounding Analysis
Generated Particulate, Scrap		23 g	Bounding Analysis
Generated Particulate, Fuel		26 g	Bounding Analysis
Total Water in Particulate		1627 g	
Residual Free Water After Drying		200 g	Controlled by 2.4.1
Total Water in MCO		1827 g = 101.5 gmol	
(Total gas from water = 101.5 gmol x 1.03 gmol H_2/gmol H_2O = 104.5 gmol)			

3.0 REQUIREMENTS GUIDE

Additional guidance beyond the specifications of Section 2.0 in this report is given in this section to assist with interpretation and implementation of the specifications.

3.1 Fuel Retrieval And Cleaning

3.1.1 Fuel Surface Area Remaining Uncleaned

Fuel cleaning is performed by placing fuel and canister in the fuel cleaning machine, which is operated for a prescribed set of conditions to provide the primary separation of fuel from corrosion products. Performance of this cleaning step is based on process validation that this operation will clean the fuel to the required cleanliness. System operation and fuel inspection corresponding to established confidence levels will assure cleanliness. Carlisle, 1997, establishes the plans for Fuel Retrieval System Process Validation. Ultimately cleaning is defined by properly operating the cleaning machine after validation has been established to that document.

3.1.2 Scraploading

3.1.2.1 Material with dimension < 1/4 inch

Material that has a dimension of less than ¼ inch is administratively controlled by specifying that no fuel or scrap is loaded in baskets without being processed by fuel cleaning equipment which has been operated at conditions specified by validation requirements tests.

3.1.2.2 Scrap < 1 inch and ≥ 1/4 inch

Scrap that is less than 1 inch and greater than or equal to 1/4 inch is administratively controlled by specifying that fuel pieces that can not be picked up by the fuel retrieval manipulator must be placed in the fines scrap region of the scrap basket.

3.1.2.3 Scrap > 1 inch

Scrap that can be handled by a manipulator will be placed in the coarse scrap section.

3.1.3 Fuel Loading

Inspection of fuel baskets prior to transport to the loading queue will indicate that fuel elements are properly positioned in the fuel basket. Inspection is to ensure that no material is wedged between the fuel assemblies, splaying out the upper ends of assemblies.

3.1.4 Fuel queuing

Fuel and scrap basket durations in the basket queue (i.e. time that baskets are in the queue) will be administratively tracked. The impact of longer queuing time on an MCO particulate and water inventory will be evaluated if basket storage times exceeds the duration in Section 2.1.4.

3.2 MCO Loading System

3.2.1 Number of Scrap Baskets

Administratively control through procedures.

3.2.2 Position of Scrap Basket

Administratively control through procedures.

3.2.3 MCO Sealing

MCO seal ring cleanliness is controlled by design of a basket loading guide. Cleanliness is administratively controlled by specifying that the basket guide must be in place during basket loading activities and cleaning the seal area prior to shield plug installation. After the basket guides are removed, the seal ledge is to be flushed with a water wand tool to remove any particles greater than or equal to 0.006 inch. Inspection of the seal by camera prior to sealing the shield plug will be performed.

3.3 Cask Loading and Transport System

3.3.1 MCO Cask Package Backfill Gas

Helium inerting will be performed through the shield plug filter trap prior to loadout to CVD. Inerting will thereby be performed through the cask lid by over pressurizing and then bleeding off the MCO and Cask (i.e., MCO communicates directly with the cask cavity through an internal MCO High Efficiency Particulate Air [HEPA] filter). The objective of inerting the MCO and cask void spaces with helium is to establish an atmosphere that remains an inflammable gas mixture as hydrogen is generated within the MCO.

3.3.2 MCO Cask Package Pressure

This will be administratively controlled to less than 20.7 kPa gage (3 psig) as measured after backfill.

3.3.3 Cask Water Fill Level

The MCO port number 3 is not used; therefore, the water in the MCO will never drain to a level below the top of the fuel. The cask water level is dictated by the MCO/Cask seal location. Any drainage needed to accommodate thermal expansion is also accounted for.

3.3.4 Transport Between K Basins and CVD

This will be administratively controlled to less than 24 hours else mitigative actions are required to be taken.

3.4 Cold Vacuum Drying

3.4.1 MCO Free Water Inventory

The limiting free water level will be measured using CVD instrumentation and the technique described in Pajunen (1997).

3.4.2 MCO Backfill Gas

3.4.2.1 Gas

MCO backfill gas will be provided by CVD systems and procedures in accordance with OCRWM requirements on the helium back fill gas per Irwin (1997).

3.4.2.2 MCO Backfill Gas Temperature

Temperature will be controlled by CVD systems and procedures.

3.4.2.3 Backfill Pressure

MCO backfill pressure will be assured by CVD systems and procedures.

3.4.2.4 MCO Integrated Leakage Rate

Leakage testing of MCOs shall be performed with CVD systems that meet the intent of the ANSI N 14.5 requirements prior to shipment from the CVD Facility to the CSB.

3.4.3 Cask Backfill Gas

3.4.3.1 Backfill Gas

Instrument air will be pumped through the Cask Annulus after draining the water. Upon completion of water drainage and air purge, no more than 1 vol % water vapor is permitted in the cask.

3.4.3.2 Backfill Temperature

No gas temperature measurements are required (i.e., insufficient gas heat capacity to alter cask/MCO temperature).

3.4.3.3 Backfill Pressure

Cask backfill pressure will be assured by CVD systems.

3.4.4 Cask Shipping Temperature

The initial cask shipping temperature will be assured by CVD systems and procedures through computer control system calculation of bulk temperature from measurements of water inlet and outlet temperatures to the cask and the ambient temperature.

3.4.5 Halogenated and/or Organic Compounds

CVD equipment and system design precludes process addition of oils and/or other organics that will not be removed at CVD operating conditions.

3.5 Cask Transport to CSB

3.5.1 Transport Between CVD and CSB

Transport time from CVD to CSB will be controlled administratively.

3.6 Canister Storage Building Systems

3.6.1 MCO Staging at CSB

MCO staging times in the CSB will be controlled administratively.

3.6.2 Leakage Rate After Welding

Leakage testing of MCOs shall be performed in accordance with an approved procedure that meets the requirements of ANSI N14.5 prior to release from the weld station into long term storage.

3.6.3 Sealed Storage Conditions

3.6.3.1 MCO Maximum Internal Pressure

MCO maximum internal pressure is met by conformance to processing steps prior to sealing.

3.6.3.2 MCO Gas Temperature

MCO gas temperature is met by proper function of the CSB vault cooling system and conformance to processing steps through sealing.

3.6.3.3 Water and Gas Inventory

Water and gas inventory is met by conformance to processing steps through sealing.

3.6.3.4 Allocation of Bound and Free Water

Allocation of bound and free water is by proper fuel cleaning and satisfying CVD product specifications.

3.7 MCO Interim Storage

Accomplished by complying with DOE program direction.

4.0 TECHNICAL BASES

Technical bases provide the rationale for the specifications of Section 2.0.

4.1 Fuel Retrieval and Cleaning

The FRS is responsible for retrieving fuel from storage locations, cleaning it and placing it in fuel and scrap baskets. Key properties related to particulate and water content originate at FRS.

4.1.1 Fuel Surface Area Remaining Uncleaned

Fuel cladding films must be removed to comply with the 80% removal assumption described in Section 4.6.3.4 in order to meet the storage requirement limitations on water content.

4.1.2 Scrap Loading

4.1.2.1 Material with dimension < ¼ inch

The fuel retrieval cleaning and loading process and systems must minimize the loading of scrap which is smaller than ¼ inch into the MCOs. This is stipulated to prevent accumulation of high concentrations of reactive surface area in the MCO and reduce the quantity of irradiated materials which could leave the MCO with the water at the CVD Facility. High concentrations of reactive surface area in an MCO would exceed the basis of the thermal calculations that support safety analyses for the CVD.

4.1.2.2 Scrap < 1 inch and ≥ ¼ inch

Scrap sized from ¼ inch to 1 inch is to be loaded only in the fine scrap region of the basket (Duncan 1997). This requirement assures that the safety margin estimated in thermal calculations for the CVD are maintained during operations. This is accomplished by limiting the volume of the basket which can be loaded with small scrap pieces to 10 percent or less of the total scrap basket volume by creation of a separate fine scrap collection area.

4.1.2.3 Scrap > 1 inch

The only limitations on larger pieces of scrap will be placement in the scrap basket, volume, and any criticality mass limits imposed by FRS for their needs. Thermal calculations allow for these.

4.1.3 Fuel Loading

The MCO fuel basket design is based on positioning fuel assemblies on end in sockets formed in the basket bottom plate. This orientation facilitates efficient packing of assemblies in baskets and promotes water drainage from the center and annular void region of each assembly. In addition, fuel drying during helium flow conditions is promoted by the alignment of assembly void regions with openings in the positioning socket.

Loading fuel material between assemblies is to be precluded based on operational considerations. Fuel pieces wedged between elements can potentially splay out the top ends of assemblies. This configuration could make it difficult to remove a fuel basket from a storage queue position or MCO (basket removal from an MCO may be required during basket loading if a basket does not seat properly).

4.1.4 Fuel queuing

Cleaned fuel in baskets queued underwater for loading in an MCO will continue to react with basin water and generate additional particulate. The basis for estimating a bounding particulate inventory in an MCO assumes a basket storage time after cleaning is limited to 30 days (Sloughter 1997). The water content of generated particulate is incorporated in the bound water allocations indicated in Section 4.6.3.4. Therefore, if fuel storage time periods exceed 30 days, process conditions will have exceeded assumptions in these basis calculations.

Particulate generation during basket queue storage is a small contributor to the MCO hydration water inventory due to the slow rate of hydrating uranium corrosion products at basin storage temperatures. Experimental data presented by Duncan and Ball (1997) indicate approximately 10 mole % of a UO_2 corrosion product would be converted to a hydrate if stored for 30 days at 60°C in 80% humidity air. Storage under water at basin temperatures of 10°C for time periods in excess of 30 days may not significantly impact the bounding particulate or water inventory of an MCO depending on how long the basket is actually stored. Therefore, if fuel queuing exceeds 30 days, the actual storage time impact on particulate and hydration formation must be evaluated and compared to the established bound. If it cannot be shown that the MCO will be within the bounding particulate and hydration water inventory limit, fuel in these baskets must be recleaned prior to loading in an MCO.

4.2 MCO Loading System

The MCO Loading System will take the loaded fuel and scrap baskets from the basket queue and load them into MCOs.

4.2.1 Number of Baskets of Scrap

Thermal hydraulic analyses of CVD upset conditions (Duncan 1997) have been based on one basket of scrap containing the bounding reactive uranium surface area loaded in an MCO. Limiting the MCO to one scrap basket produces a loading configuration consistent with the thermal analyses performed to date.

4.2.2 Position of Basket of Scrap

Thermal hydraulic analyses of CVD conditions were based on positioning a scrap basket in the top position of the MCO (Duncan 1997). Loading scrap baskets only in the top position produces a configuration consistent with the thermal analyses performed to date.

4.2.3 MCO Sealing

A seal leak will prevent completion of the CVD process or MCO leak check at CVD and could lead to returning the MCO to K Basins to establish the seal. Due to seal configuration and diameter, vendor recommendations indicate that particulate of a diameter greater than half the seal thickness needs to be cleaned from sealing surfaces to preclude disrupting the sealing function. Currently, the seal is planned to be 0.012 inch thick. Therefore, particulate greater than 0.006 inch in diameter must be excluded from depositing on the sealing surface.

4.3 Cask Loading and Transport System

The package loaded on a semi-trailer for transport to the CVD Facility consists of the loaded and vented MCO inside of a sealed cask. During the package preparation, air in the void space at the top of the MCO and cask must be replaced by inert gas to preclude developing of a flammable gas mixture. Furthermore, the shipping window is based on the generation rate of gases such as hydrogen to preclude over pressurization of the cask.

4.3.1 MCO Cask Package Backfill Gas

The uranium fuel will react with water in the MCO to generate hydrogen during transport to CVD. The MCO cover gas needs to be inert to prevent flammable mixtures of hydrogen and oxygen from forming during the transport window. Flammable gas mixtures are precluded by reducing the void space oxygen concentration to less than 4 vol % prior to shipping. As hydrogen accumulates in the cask void space, the initial oxygen concentration decreases and the gas mixture remains in a non-flammable regime.

The SNF is to be transferred from the K Basins to the CVD Facility in a flooded condition. This means that water will be present in the MCO and Cask to within 10 cm (4 inches) of the bottom of the MCO shield plug main body. Furthermore, the MCO is vented to the void space at the top of the cask during transfer. This combined MCO and Cask void space will be filled with helium to ensure that accumulation of flammable gas concentrations will be precluded during shipment (Edwards 1997).

4.3.2 MCO Cask Package Pressure

During the flooded transfer conditions from the K Basins to the CVD Facility the MCO and cask cavities are backfilled with helium gas that is relatively oxygen free to a pressure sufficient to ensure that any leakage would be from the package to the environment while keeping the initial pressure low to allow for additional pressurization due to hydrogen gas generation (Edwards 1997). A maximum pressure of 20.7 kPa, gauge (3 psig) is specified in Edwards (1997).

4.3.3 Cask Water Fill Level

In the Safety Analysis Report for Packaging (SARP) analyses of pressurization rates (see Section 4.3.2 of this document) during transportation activities are based on a minimum void space volume. Therefore, the MCO and the cavity between the MCO and the MCO Cask are filled with water during transportation from the K Basins to the CVD Facility in the 100 K Area. The water in the MCO is slightly contaminated water directly from the K Basins, while the water in the cask cavity is demineralized water. The water level in the MCO is approximately 10 cm (4 inches) below the bottom of the shield plug, while the water level in the cask cavity is at the same level, which is 41.4 cm (16.3 inches) below the top of the cavity. The MCO is vented through a HEPA filter to the cask cavity during this transfer to provide a larger volume for the gas generated from corrosion (Edwards 1997).

4.3.4 Transport Between Loading and CVD

The SARP (Edwards 1997) limits the transfer time to 24 hours. Mitigation actions specified in Edwards (1997) must be implemented if transfer times exceed this limit.

4.4 Cold Vacuum Drying

The CVD Facility drys the fuel allowing it to be transported to the CSB and stored there for up to 40 years.

4.4.1 MCO Free Water Inventory

An inventory of free water in an MCO after drying (200 g) has been allocated as a contributor to the total MCO pressure during storage based on the feasibility of identifying tests or procedures that confirm compliance with the specified limit. Section 4.6.3.4 describes the overall basis for allocating water to different constituents that may exist in an MCO during storage.

4.4.2 MCO Backfill Gas

4.4.2.1 Gas

Helium is the MCO backfill gas based on thermal property performance. Heard (1996) compared MCO fuel temperatures during final storage in the CSB assuming helium, nitrogen, and argon as the backfill gas. Helium significantly reduced the peak fuel temperature. Subsequent thermal analyses (Duncan and Ball 1997), which assume a helium backfill gas, have been used as the basis for gas temperature defining limit on MCO water inventory during storage (see Section 4.5.2.1). Therefore, helium must be used as a backfill gas for the water limits in this specification to be applicable. Helium will be the only inert gas utilized at the CVD Facility and will be controlled to Office of Civilian Radioactive Waste Management (OCRWM) requirements per Irwin (1997).

4.4.2.2 MCO Backfill Gas Temperature

The MCO temperature during backfill operation impacts the molar quantity of added gas. The basis for maximum pressure during storage assumes backfill gas quantities are specified at 25°C. Backfilling the MCO at a lower temperature, to the same backfill pressure range, would result in adding a molar quantity of gas that exceeds the contribution allocated in Table 4-1. Therefore, the backfill gas temperature must be greater than or equal to 25°C when establishing that the backfill pressure criterion is complied with.

The maximum backfill gas temperature impacts the minimum molar quantity of helium added to an MCO. The MCO gas temperature of 35°C at the minimum backfill pressure specified in Section 4.4.2.3 results in a minimum helium inventory consistent with that used to evaluate leak rate criteria in Sherrell (1998).

4.4.2.3 Backfill Pressure

The MCO backfill pressure after drying is based on establishing a positive internal gas pressure within the MCO with respect to atmospheric conditions to preclude air in leakage during transport and storage. A minimum backfill pressure of 40 kPa, gage (20.5 psia) supports maintaining a positive internal gage gas pressure at MCO temperatures as low as -27°C. This minimum backfill pressure supports maintaining a positive internal gage pressure for up to 15 months based on the leakage rate criterion for the MCO mechanical seal specified in Section 4.4.2.4 (Sherrell 1998). The maximum backfill pressure of 60 kPa, gage (23.5 psia) is based on the total pressure allocation to backfill gas specified in Section 4.6.3.3.3.

4.4.2.4 MCO Integrated Leakage Rate

Maintaining MCO containment is an essential requirement throughout processing. Smith, 1997 specifies that the MCO shall maintain its containment capabilities during and after being subjected to the design basis accidents. During Hanford on-site transportation, process operations, and staging the total gaseous leakage across the MCO pressure boundary including process connection seals but excluding controlled flow through any port, shall not exceed 1×10^{-4} std cc/sec. This gaseous leakage rate is based on a clean seal and a clean sealing surface at the final mechanical closure boundary (Smith 1997).

The safety consequences during CVD processing are controlled by the CVD Safety Class Helium System. Therefore, this leakage rate criteria does not apply during processing in the CVD. During transport the cask provides the containment for the MCO.

4.4.3 Cask Backfill Gas

4.4.3.1 Backfill Gas

Based on a sealed MCO, air provides suitable environment for the MCO during transport and storage. The annulus region (between Cask and MCO) is used for controlled heating and cooling during processing at the CVD Facility. This region is dried prior to transporting an MCO to the CSB. The thermal conductivity of water vapor is approximately the same as the thermal conductivity of nitrogen over the temperature range (0°C to 200°C) at one atmosphere. Therefore, the presence of water vapor in the cask annulus does not degrade the thermal characteristics of the MCO/Cask package. The dew point of a 1 vol % water vapor-gas mixture is approximately 8°C. Therefore, limiting the water vapor content of the annular space to less than 1 vol % does not degrade the overall annular space thermal conductivity and precludes the presence of liquid water if the Cask temperature does not decrease below 8°C (45°F) during transport.

4.4.3.2 Backfill Temperature

No special considerations are associated with the molar quantity of air in a cask prior to shipping. Therefore, ambient temperature is specified for the cask backfill temperature.

4.4.3.3 Backfill Pressure

No special considerations are associated with the molar quantity of air in a cask prior to shipping. Therefore, ambient pressure is specified for the cask backfill pressure.

4.4.4 Cask Shipping Temperature

Current analyses indicate that the shield plug temperature on receipt at the CSB will be bounded at 40°C (104°F) for an initial shipping temperature of 25°C (77°F) [refer to Figure 4-8 of Kee 1997]. This temperature is considered low enough for operator handling activities in the CSB receiving area. This represents the basis for specifying a cask temperature of less than 25°C prior to shipping.

4.4.5 Halogenated and/or Organic Compounds

The manufacturing and handling of the MCO shall not result in residues containing significant quantities of halogenated compounds or oils with a low-vapor pressure. Therefore, the introduction of halogenated oils or oils with a low-vapor pressure into an MCO shall be precluded throughout the life cycle of the MCO. Furthermore, this is an OCRWM requirement for the CVD Facility per Irwin (1997).

4.5 Cask Transport to CSB

Upon completion of cold vacuum drying, the MCO and Cask are prepared for transport to the CSB.

4.5.1 Transport Between CVD and CSB

Sherrell (1998) evaluates hydrogen leakage from an MCO assuming the MCO mechanical seal leak rate is established to be < 1 x 10^{-4} std cc/sec as specified in Section 4.4.2.4. Based on this analysis, the hydrogen concentration of gases in the cask cavity will exceed the flammability limit of 4 vol % in approximately 5 days. Mitigation actions must be implemented if transfer times exceed this limit.

4.6 Canister Storage Building Systems

After arrival at the CSB (and possibly some amount of staging/storage time), the MCOs are welded for long term storage. Process requirements to be imposed on the final package closure are specified in this section.

4.6.1 MCO Staging at CSB

The MCO staging time limit is based on the need to maintain a positive pressure in the MCO while maintained in the CSB storage tube air atmosphere. This positive pressure precludes oxygen leakage into the MCO. Sherrell (1998) evaluates helium leak rates from an MCO assuming the MCO mechanical seal leak rate is < 1 x 10^{-4} std cc/sec, as specified in Section 4.4.2.4. Based on this analysis and the minimum helium backfill addition specified in Section 4.4.2.3, the time in staging must be limited to 15 months in order to maintain a positive pressure within a MCO under extreme low storage temperature conditions.

4.6.2 Leakage Rate After Welding

The maximum leakage that is permitted from the "welded" package is specified in Smith (1997) as 1 x 10^{-7} std cc/sec.

4.6.3 Sealed Storage Condition

4.6.3.1 MCO Maximum Internal Pressure

The maximum pressure limit is based on the MCO design differential pressure limit of 150 lbf/in^2 (Smith 1997). Based on atmospheric pressure outside the MCO, the differential pressure translates into an absolute pressure of 165 lbf/in^2 [abs] (1.1 Mpa). The internal pressure specification is based on maintaining the total pressure below the structural capability of the MCO for American Standard of Mechanical Engineers (ASME) Section III Service Level A for all routine operations. Design analysis may identify Service Level B, C, or D events which will accommodate transients above this level, consistent with ASME Section III normal operation. This is typically with the corroded fuel in the MCO to the end of its lifetime with maximum operational pressure and temperature; the evaluation also assesses whether the initial condition is the worst credible.

4.6.3.2 MCO Gas Temperature

The temperature used to establish the allowable amount of gas in an MCO is based on the maximum projected gas temperature during storage in the CSB. Design criteria for the CSB limit the maximum allowable MCO wall temperature to 270°F (132°C) during storage (Swenson 1996). Therefore, the maximum gas temperature calculated by Duncan and Ball (1997) is 157°C.

4.6.3.3 Water and Gas Inventory in MCO

Controlling the MCO total water inventory after drying is used to maintain the worst case projected internal pressure within MCO design limits. The water limit is derived from the total molar quantity of gas corresponding to the pressure limit at worst case storage conditions. This molar quantity is allocated to the mechanisms that introduce gas into the MCO. The water limit represents a difference between the total allowable gas quantity and other identified gas generation mechanisms. Table 4-1 summarizes the total gas and contributors used as a basis for developing a water inventory that maintains the MCO pressure within design constraints. The following sections describe the basis for gas quantities associated with each contributor shown in Table 4-1.

4.6.3.3.1 Total Gas Limit in MCO

The limiting molar quantity of gas in an MCO is based on the maximum allowable gas pressure in the minimum projected MCO void volume at the maximum projected storage temperature after sealing. The ideal gas law is used to convert these parameters into a limiting molar quantity of gas. Total gas pressure and temperature are based on Sections 4.6.3.1 and 4.6.3.2.

The limiting molar quantity of gas is based on a 500 L free-gas volume of a MCO loaded with 270 E Length Mk IV fuel assemblies (6.34 MTU of Mk IV fuel). The free volume is based on an MCO internal volume of 953 L derived from internal dimensions shown on drawing H-2-828041, Rev. 0. Mk IV fuel basket displacement volumes are based on a basket mass of 199 lb, as indicated on drawing H-2-828070, Rev. 0, and the density of stainless steel (8 g/cm^3) yielding a displacement volume of 11.3 L per basket. Fuel assembly displacement volumes for E length fuel elements are derived from dimensions in Willis (1995) resulting in a displacement volume of

Table 4-1. Allowable Amounts of Gas in the Sealed Multi-Canister Overpack.

Constituent	Gas in multi-canister overpack, gmol	Explanation
Total gas	159	Maximum pressure of 165 lbf/in^2 [abs] (1.1 Mpa [abs]) at 315°F (157°C) gas temperature with a 500 L gas volume.
Contingency	15.9	10 percent contingency allowance for uncertainty in MCO void volume, and miscellaneous pressure contributors not explicitly considered (organics, etc.).
Backfill gas	32.7	The MCO will be initially filled with helium to a positive gage pressure not to exceed 23.5 lbf/in^2 [abs] at 77°F (25°C).
Noble gases (Kr, Xe)	< 0.1	Fission product noble gases released as a result of corrosion of the fuel, based on a water inventory of 2,000 g in a sealed MCO.
He	< 0.1	Helium is released from alpha decay of transuranics and fuel. This is an integrated value, not corrected for fuel matrix holdup.
Oxygen	5.7	Oxygen concentration not to exceed 4 vol. % to preclude flammable gas mixtures.
Total water and hydrogen	104.5	See Section 4.6.3.3.7

1.47 L/assembly. These factors result in a minimum free volume estimate of 500 L (953 - 5x11.3 - 270x1.47). Other fuel loadings, including a scrap basket or variety of MK IA fuel loadings, result in larger calculated void volumes.

Based on the limiting pressure, temperature, and minimum volume, the limiting molar quantity of gas is found as follows.

$$Gas\ quantity = \frac{PV}{RT} = \frac{(\frac{165 psia}{14.7 psia/atm})(500 L)}{(0.082 \frac{atm\text{-}L}{gmol\text{-}K})(273 + 157 K)} = 159\, gmol$$

4.6.3.3.2 Contingency

A 10 percent contingency has been maintained to accommodate uncertainties in the potential for pressure contribution from trace materials not specifically considered (e.g. organics) for the allowed inventory of components that could contribute to internal pressure. Organic materials and halide compounds can contribute gaseous products due to both volatilization and radiolysis. Gaseous products produced by these materials will add to the internal pressure of the container and over time can also contribute to existing corrosion mechanisms as well as introducing new corrosives.

Contribution to MCO pressure from all residual organics present in the MCO including those associated with debris will be considered and shall not exceed the MCO 10 percent pressure contingency allowance without a corresponding reduction in the allowed amount of water and hydrogen in the MCO. When considering the significance of potential organic inventories, it should be noted that 100 grams of a hydrocarbon releasing only hydrogen as a gas upon radiolysis could consume more than one half of the 10 percent pressure contingency allowance.

The degradation of organic and other compounds via chemical reaction or radiolysis may release hydrogen, oxygen, and halides. The gaseous products increase pressure in the MCO. Hydrogen and oxygen from organic degradation can also lead to increased fuel and MCO corrosion and contribute to deflagration/detonation concerns. Halides can be particularly corrosive to stainless steel.

Organic materials and halide compounds could potentially be introduced during normal MCO fabrication and handling processes (e.g., by use of cleaning compounds/cutting oils and during off normal events, e.g., vacuum system failure leading to backflow of pump oil into the MCO).

The radiolytic decomposition rate (G values) for most organics including vacuum pump oil and plastics are generally several times higher than the G values for water.

When evaluating allowable organic inventories, consideration must also be given to the release of other gaseous decomposition products. Given the increased G value for organic decomposition, consideration must also be given to the radiolytic oxygen production rate from residual organic materials.

4.6.3.3.3 MCO Backfill Gas

The pressure inside the MCO upon sealing is established at a positive pressure with respect to atmospheric conditions to preclude air in leakage. The allocation of total gas inventory to the backfill gas is limited by a selected set of conditions in excess of the minimum backfill requirements. Increasing the quantity of backfill gas added, decreases the allowable quantity of water that can be in an MCO after drying. The maximum backfill conditions selected are based on backfilling to 23.5 psia at 25°C. The maximum backfill gas pressure was selected to provide a practical control range above the minimum backfill pressure (20.5 psia) required in Section 4.4.2.3. This results in an allocation of 30.6 gmol of gas added to an MCO with minimum void volume. The actual molar quantity of backfill gas added will vary with the MCO void volume when the addition is based on temperature and pressure. However, since the other contributors are fixed molar quantities, the effect of other contributors on MCO pressure is reduced as the MCO void volume increases. Therefore, if the molar quantity of backfill gas exceeds this allocation in Table 4-1 due to a larger MCO void volume, the total pressure criteria will not be exceeded.

4.6.3.3.4 Noble Gas Release

Noble gas release is estimated based on an assumed water inventory corroding uranium metal fuel to release xenon and krypton. Willis (1997) does not contain estimates of trace elements in fuel, such as xenon. Therefore, an estimate of noble gas release is based on the radionuclide content estimated for Mk IV fuel irradiated to produce 16% ^{240}Pu that is cooled 10 years (a conservative amount of time) in Schwarz (1997, see pg. V2.545). Based on these estimates, the fuel krypton content is 45.45 g/MTU and xenon content is 628.6 g/MTU. The fuel corrosion is approximated for a total water content of 2,000 g (111 gmol). Note that the water content estimate is refined in Section 4.6.3.3.7. The following simplified corrosion stoichiometry results in 1 gmol of uranium corroded per 2 gmol of water reacted.

$$U + 2H_2O \rightarrow UO_2 + H_2$$

Therefore, the quantity of uranium corroded by 111 gmol of water is approximately 55.5 gmol U, or 13.2 kg uranium reacted. Based on molecular weights of 85 g/gmol for krypton and 131 g/gmol for xenon, the fuel noble gas content is 5×10^{-4} gmol Kr/kg U and 5×10^{-3} gmol Xe/kg

U. The noble gas release by metal corrosion is then estimated at 0.07 gmol Kr+Xe, or less than 0.1 gmol gas.

4.6.3.3.5 Helium Decay Product

Helium gas release is estimated based on an assumed water inventory corroding uranium metal fuel. Willis (1995) does not contain estimates of tracer elements in fuel, such as helium. Therefore, an estimate of helium gas release is based on the radionuclide content estimated for Mark IV fuel irradiated to produce 16% ^{240}Pu that is cooled 60 years (conservative value) (in Schwarz 1997, see pg. V2.533). Based on these estimates, the fuel helium content is 0.29 g/MTU.

The fuel corrosion is approximated as in Section 4.6.3.3.4 and 13.2 kg of uranium reacted. Based on a molecular weight of 4 g/gmol for helium, the fuel helium gas release by metal corrosion is then estimated at 0.00096 gmol He, or less than 0.001 gmol gas which is much less than the 0.1 gmol of He gas allowed for in Table 4.1

4.6.3.3.6 Oxygen

Oxygen is generated as a decomposition product of water through radiolysis. The limit of 4 volume percent oxygen is needed to prevent an undesirable rapid reaction with hydrogen, which would produce MCO pressurization (Cowan 1997). NRC Regulatory Guide 1.7 indicates that oxygen concentration should not exceed 5 volume percent when more than 4 volume percent hydrogen is present if burning is to be avoided (NRC 1978). Oxygen gettering by uranium metal is projected to maintain low concentrations of oxygen in an MCO.

To control the oxygen concentration below 4 volume percent: 1) the oxygen concentration in the MCO when the MCO is sealed will be confirmed to ensure that it is less than 4 volume percent, and 2) the presence of sufficient oxygen consuming material in the MCO will be verified to ensure that the rate of oxygen production in the MCO due to radiolysis and other mechanisms is less than the rate of oxygen consumption. An allocation of 4% of the total molar gas quantity, less contingency, at maximum pressure is included as a contribution from oxygen to allow for the build up of a driving force for oxygen consumption reactions during the storage period. This results in allocating (0.04 x 143.1) = 5.7 gmole of gas for oxygen.

4.6.3.3.7 Water and Hydrogen

Water actively supports corrosion. During corrosion, water reacts and forms an oxide layer and released hydrogen gas. In addition, radiolytic decomposition of water will also occur, producing hydrogen and oxygen gases. As the temperature in the MCO increased, volatilization of water also will increase. Water must be controlled to limit pressure in the MCO and the buildup of hydrogen.

Some water may be associated with the oxide layers of the cladding and the MCO. Most of the water will be bound with the oxides in fuel particulate and in the oxide layers of exposed uranium. The maximum allowable water/hydrogen limit (Table 4-1) is 104.5 gmol is obtained by difference between the total gas allowable and contributors described above. Water and hydrogen produce comparable MCO pressurization due to the equimolar stoichiometry of the uranium metal corrosion reaction. Therefore, one mole of hydrogen is produced per mole of water reacted with uranium metal. Radiolytic water decomposition also produces up to one mole of hydrogen per mole of water (oxygen generated from water radiolysis is addressed in Section 4.6.3.3.6).

Water can potentially react with uranium hydride to produce hydrogen based on the following stoichiometry.

$$UH_3 + 2H_2O \rightarrow UO_2 + 3.5H_2$$

This results in producing 1.75 moles of hydrogen per mole of water reacted. Plys (1997) estimates from dry air reaction data on N Fuel that 4% of the N Fuel reacting surface can be associated with the uranium hydride reaction. Assuming the water vapor reaction rate with a uranium metal surface and uranium hydride surface is approximately the same on a uranium mass basis allows estimate a composite hydrogen generation stoichiometry for N Fuel of (0.96 + 0.04x1.75) 1.03 moles of hydrogen per mole of water reacted. Therefore, the MCO hydrogen/water allowable limit in Table 4-1 is maintained if the water inventory is less than (104.5/1.03) 101.5 gmol. This corresponds to a water mass limit of 1,827 g. The limit of 1,827 g of water per MCO should be large enough to allow demonstration of compliance, even with the current uncertainty in the amount to sludge that will be retained with the fuel after cleaning and the uncertainty of the selected processes to dry retained sludge.

4.6.3.4 Allocation of Bounding Water

Duncan and Ball (1997) summarize maximum estimates for the bound water content of solids (fuel particulate and fuel coatings) in an MCO. The maximum bound water estimate from solids is 1,890 g, as documented in Duncan and Ball (1997). This bound water estimate incorporates a fuel cleaning specification of 70% removal for aluminum hydroxide surface films. The contingencies considered in the above sections require a reduction of the bound water estimate documented in Duncan and Ball (1997). This was achieved by specifying a tighter cleaning specification (80% removal of cladding films) for the Fuel Retrieval System.

While free water removal is expected to be complete, configurations can by hypothesized where water is trapped in fuel pockets or cracks. Pajunen (1997) evaluates tests and operating conditions required to show that the residual free water in an MCO is less than 200 g. Therefore, an allocation of 200 g free water has been included in the consideration of total water inventory. The following list summarizes the MCO bound and free water allocated to system specifications.

-	Water in cladding film, scrap	420 g
-	Water in cladding film, fuel	436 g*
-	Water in oxide film, scrap	33 g
-	Water in oxide film, fuel	39 g
-	Water in scrap particulate	410 g
-	Water in fuel particulate	240 g
-	Water in scrap generated particulate	23 g
-	Water in fuel generated particulate	26 g
	Total water in particulate	1627 g
-	Residual free water after drying	200 g
	Total water in MCO	1827 g

* Fuel surface cleaning criteria increased from 70% of surfaces cleaned, as used in Duncan and Ball (1997), to 80% of surfaces cleaned. Remainder of bound water contents as in Duncan and Ball (1997).

4.7 MCO Interim Storage

The MCO structure and components, as well as CSB systems, are designed for a 40 year life (Smith 1997 and Swenson 1996). Prior to expiration of that time period, the SNF will require further processing, other storage or evaluations that these system(s) lives can be extended without jeopardizing safety.

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A. N. Praga	R3-86	X			
D. R. Precechtel	X3-85	X			
W. H. Rasin	R3-11	X			
M. A. Reilly	R3-86	X			
D. L. Sherrell	R3-86	X			
E. J. Shen	X3-75	X			
K. E. Smith	R3-86	X			
J. A. Swenson	R3-11	X			
C. A. Thompson	R3-86	X			
J. E. Turnbaugh	R3-15	X			
SNF Project Files	R3-11	X			
Fluor Daniel Hanford					
E. W. Gerber	R3-11	X			
R. L. McCormack	R3-11	X			
M. J. Wiemers	R3-11	X			

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Distribution	Process Engineering	Date 11/25/97
Project Title/Work Order		EDT No.
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Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Fluor Daniel Northwest					
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E. A. Nelson	R3-86	X			
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Department of Energy, Richland Operations Office					
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