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ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 648621

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, Process Engineering, R3-86, 376-7115	[] Yes [X] No	10/21/98
	6. Project Title/No./Work Order No.	7. Bldg./Sys./Fac. No.	8. Approval Designator
	Spent Nuclear Fuel Project	N/A	SQ
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.)	10. Related ECN No(s).	11. Related PO No.
	HNF-SD-SNF-OCD-001, Rev 2	N/A	N/A

12a. Modification Work	12b. Work Package No.	12c. Modification Work Complete	12d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	NA	NA Design Authority/Cog. Engineer Signature & Date	NA Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

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

Extensive modifications to update based on reference modifications. Changes summarized as follows:
Section 1 - Expanded introduction
Section 2 - Reformatted specification to table form. Modified the following specifications: Fuel Cleaning, Number of Scrap Baskets in MCO, Water content of cask backfill gas after CVD, Changed MCO Gas Temperature to MCO Wall Temperature. Also clarified gas composition criteria, staging based on 1 MCO/storage tube and interim storage based on 2 MCO/storage tube.
Section 3 - Expanded/clarified requirements guide descriptions.
Section 4 - Updated contents based on revisions in references.
Section 5 - Updated reference list.

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

Update of SNF Project Product specification to reflect updated references.

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

See attached distribution.

RELEASE STAMP

DATE: OCT 22 1998 STA: 4 HANFORD RELEASE ID: 2

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ENGINEERING CHANGE NOTICE

1. ECN (use no. from pg. 1): 648621

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

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	[]	Call 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
HNF-SD-SNF-TI-015/Rev 5		

21. Approvals

Signature	Date	Signature	Date
Design Authority SEE OTHER		Design Agent	
Cog. Eng. A. L. Pajunen	10/22/98	PE	
Cog. Mgr. J. R. Fredericksen	10/22/98	QA	
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Environ.		Environ.	
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		DEPARTMENT OF ENERGY	
		Signature or a Control Number that tracks the Approval Signature	
		ADDITIONAL	

SPENT NUCLEAR FUEL PROJECT PRODUCT SPECIFICATION

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COGEMA Engineering Corp., Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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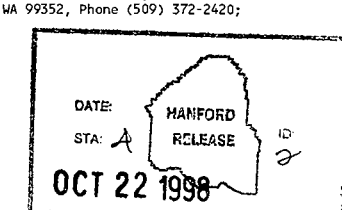
Key Words: N-Reactor fuel, MCO, CVD, FRS, SNF, SNF Project, product, specification

Abstract: This document establishes the limits and controls for the significant parameters that could potentiall 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.

10/22/98
Release Approval Date



Release Stamp

Approved for Public Release

RECORD OF REVISION	(1) Document Number HNF-SD-SNF-OCD-001	Page 1

(2) Title
SPENT NUCLEAR FUEL CONDITIONING PRODUCT CRITERIA

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) Initial release on EDT 612998	C. R. Miska	J. R. Frederickson
1	Complete rewrite and name change on ECN 645045	AL Pajunen	JR Frederickson
2	Update of new requirements on cleaning, pressure limits, and associated parameters - ECN 645062	AL Pajunen	JR Frederickson
3 RS	Update expanding descriptions and revising based on updates to references. Section 1 - expand to describe scope Section 2 - Reformate as table. Modified fuel cleaning, number of scrap baskets, water content of cask backfill gas after CVD, changed MCO gas temperature to MCO wall temperature. Clarified gas composition, staging and interim storage time limit criteria. Section 3 - Expanded/clarified descriptions Section 4 - Updated contents based on reference revisions. Section 5 - Updated reference listing. ECN 648621	AL Pajunen	JR Frederickson 10/27/98

SPENT NUCLEAR FUEL PROJECT PRODUCT SPECIFICATION

Table of Contents

1.0 INTRODUCTION

The process for removal of Spent Nuclear Fuel (SNF) from the K Basins has been divided into major sub-systems. The Fuel Retrieval System (FRS) removes fuel from the existing storage canisters, cleans it, and places it into baskets. The Multi-Canister Overpack (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.

Product specifications are limits and controls established for each significant parameter at interfaces between major sub-systems that potentially affects the overall safety and/or quality of the Spent Nuclear Fuel packaged for transport to dry storage. The product specifications in this document cover the SNF packaged in MCOs to be transported throughout the SNF Project. The description of the product specifications are organized in the document as follows:

- Section 2.0 – Summary listing of product specifications at each major sub-system interface.
- Section 3.0 – Summary description providing guidance as to how specifications are complied with by equipment design or processing within a major sub-system.
- Section 4.0 – Specific technical basis description for each product specification.

2.0 SPECIFICATIONS

Product specifications for the Spent Nuclear Fuel (SNF), Multi-Canister Overpack (MCO), and Cask are provided to ensure that packages leaving a sub-system satisfy the requirements of all subsequent process sub-systems such that the final MCO can be stored for a 40 yr time period. The specifications in this document are intended to provide requirements for individual sub-project performance specifications.

Interface Characteristic	Specification
2.1 Fuel Retrieval and Cleaning	
2.1.1 Fuel Cleaning	
2.1.1.1 Films and adhering particulate	No film or adhering particulate removal required
2.1.1.2 Canister particulate	All fuel and scrap must be processed by the fuel cleaning machine prior to loading in a basket. The fuel cleaning machine must be operated at conditions demonstrated to produce 99% confidence that no more than 15% of the canisters fail the cleaning criteria as described in Section 4.1.1.2.
2.1.2 Scrap Basket Loading	
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 fines region of scrap basket.
2.1.2.3 Scrap > 1 inch	Placed in scrap basket.
2.1.3 Fuel Basket Loading	Fuel and fuel segments must be loaded to form element pairs and remain in fuel basket sockets.
2.1.4 Fuel and Scrap Basket Queuing	Basket queue storage < 30 days.
2.2 MCO Loading System	
2.2.1 Number of Scrap Baskets in MCO	≤ 2
2.2.2 Position of Scrap Baskets	Top and/or bottom basket position.
2.2.3 MCO Seal	Load baskets and install shield plug per procedure.
2.3 Cask Loading and Transport System	
2.3.1 MCO/Cask Package Backfill Gas Composition	
2.3.1.1 Added Gas	99.9% Helium
2.3.1.2 Package Void Space Gas	< 2% Oxygen
2.3.2 MCO Cask Package Pressure	2 psig to 3 psig at ambient temperature.
2.3.3 Cask water fill level	Within 4 inches of bottom of shield plug (both MCO and cask)
2.3.4 Transport between K Basins and CVD	< 24 hours

Interface Characteristic	Specification
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 Composition	
2.4.2.1.1 Added Gas	99.9% Helium
2.4.2.1.1 MCO Void 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	5.8 psig to 8.8 psig
2.4.2.4 MCO Main Seal Integrated Leakage Rate	$<10^{-5}$ std cc/sec
2.4.3 Cask Backfill Gas	
2.4.3.1 Backfill gas	Air with < 0.5 vol% water vapor.
2.4.3.2 Backfill temperature	Ambient
2.4.3.4 Backfill pressure	Ambient
2.4.4 Cask Shipping Temperature	≤ 25 °C (at start of shipment).
2.4.5 Halogenated and/or Organic Compounds	None added by process.
2.5 Cask Transport to CSB	< 234 hr
2.6 Canister Storage Building Systems	
2.6.1 Mechanically Sealed MCO Stored at CSB*	< 3.5 years with 1 MCO per storage tube
2.6.2 Leakage rate after cover cap welding	$\leq 10^{-7}$ std cc/sec from each MCO components and seal weld
2.6.3 Sealed Storage Condition	
2.6.3.1 MCO maximum internal design pressure	450 psig
2.6.3.2 MCO Wall Temperature	≤ 132 °C
2.6.3.3 Water and Gas Inventory in MCO	Controlled by process systems and bounding analyses. See Section 4.6.3.3 for contribution summary.
2.7 MCO Interim Storage	≤ 40 years with 2 MCOs per storage tube

*- Material selection changes are currently under consideration for the MCO seal that would reduce the maximum design pressure of a mechanically sealed MCO to approximately 150 psig. This design change would not impact the MCO design pressure of 450 psig when in sealed storage (after welded cover cap installation).

3.0 REQUIREMENTS GUIDE

The following discussion provides an overview of activities performed within a process step implementing the specifications of Section 2.0 to assist with specification interpretation.

3.1 Fuel Retrieval and Cleaning

3.1.1 Fuel Cleaning

Fuel cleaning is performed by retrieving a canister of fuel the basin storage racks and processing it in the fuel cleaning machine. This operation provides the primary separation of fuel from corrosion products, reducing the quantity of material containing hydrated water loaded in a MCO. Performance of this cleaning step is based on identifying a set of operating conditions (e.g., time, rotation speed, water flowrates) that produce fuel that satisfy the canister cleaning criteria. Once a set of conditions is established, a process validation procedure is performed to demonstrate that the cleaning criteria are satisfied at a confidence level consistent with bounding particulate inventory analyses in Sloughter (1998). The actual set of cleaning machine operating conditions and process validation activity will be performed during startup activities. Therefore, the operating conditions can not be specified at this time. However, the criteria used to relate performance to the bounding particulate analysis are described in Section 4.1.1. Ultimately, cleaning is defined by processing all fuel through a properly operating cleaning machine after validation has been established in accordance with Shen, 1997.

3.1.1.1 Films and Adhering Particulate

The fuel cleaning machine is expected to remove some of films or adhering particulate during processing. However, the development of a conservative bound assumes no credit for removal of these materials from fuel elements in the bounding analysis by Sloughter (1998) due to the difficulty in quantifying the residual film and adhering particulate on a production basis (see Section 4.1.1.1).

3.1.1.2 Canister Particulate

The fuel cleaning criteria are based on separation of canister particulate (loose particulate collected between elements in the bottom of the canister) from fuel elements and scrap prior to loading these materials in baskets (see Section 4.1.1.2 for the criteria description). All fuel bearing materials loaded in either type of basket must be processed by the cleaning machine in order for the analysis determining the MCO bounding particulate inventory is valid.

3.1.2 Scrap Basket Loading

Scrap consists of all fuel bearing material that can not be loaded in a fuel basket. Therefore, scrap can consist of material with dimensions as small as ¼ inch, but can also consist of pieces as large as entire fuel elements which do not fit in bottom plate sockets of the fuel basket.

3.1.2.1 Material with dimension < 1/4 inch

Loading of material that has a dimension of less than ¼ inch in a MCO is administratively controlled by specifying that no fuel or scrap is loaded in baskets without being processed by the fuel cleaning machine operated at conditions determined during validation tests. Equipment designs contain ¼ inch screens to support this size classification of materials.

3.1.2.2 Scrap < 1 inch and ≥ 1/4 inch

The location and total volume of small scrap pieces (less than 1 inch and greater than or equal to I/4 inch) loaded in an individual scrap basket 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 (center most compartments) of the scrap basket.

3.1.2.3 Scrap > 1 inch

Scrap that can be handled by a manipulator will be placed primarily in the coarse scrap section of a scrap basket. However, scrap pieces larger than 1 inch can also be placed in the scrap basket fines section (center compartments) if needed during operation.

3.1.3 Fuel Basket Loading

Fuel element pairs are loaded in a fuel basket if at least one end of the outer element fits within the hole machined in the plate of the fuel basket and the inner element fits within the outer element. Both elements must seat within the fuel basket holes such that the top of either element does not exceed the fuel basket height. Fuel element segments, greater than 3 inches long, may be stacked (outer segments on intact inner or inner segments in intact outer) to form element pairs in a fuel basket position.

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 and Scrap Basket 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 exceed the duration in Section 2.1.4.

3.2 MCO Loading System

3.2.1 Number of Scrap Baskets in MCO

Administratively controlled to no more than 2 scrap baskets per MCO through procedures.

3.2.2 Position of Scrap Baskets

Administratively controlled to placement in the top and/or bottom position through procedures.

3.2.3 MCO Seal

The 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 that may interfere with proper sealing. Inspection of the sealing face will be performed by camera prior to seating the shield plug.

3.3 Cask Loading and Transport System

3.3.1 MCO/Cask Package Backfill Gas Composition

The MCO is vented to the cask during the transfer between the basin and CVD facility. An inerting procedure is performed after installing the cask lid to preclude development of a flammable gas mixture in the MCO/cask void space as hydrogen is generated within the MCO.

3.3.1.1 Added Gas

Helium is used as the inert gas added to the MCO/cask void space.

3.3.1.2 Package Void Space Gas

After cask lid installation, the package void space gas composition is equivalent to air. A series of pressure-bleed cycles, introducing helium into the closed cask, is used to reduce the oxygen concentration of the MCO/cask void space. The number of cycles to achieve 2% oxygen depends on the operating pressure selected (e.g., 6 cycles to 20 psig or 3 cycles to 45 psig achieves 2% oxygen in the package void space).

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 cask water level is dictated by the MCO/Cask seal location. Any drainage needed to accommodate thermal expansion is also accounted for in the design.

3.3.4 Transport Between K Basins and CVD

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

3.4 Cold Vacuum Drying

3.4.1 MCO Free Water Inventory

A bound for the residual free water inventory after CVD processing will be established based on the procedure described in Pajunen, 1998a. This procedure consists of holding the MCO at a temperature greater than 40 °C and pressure less than 12 torr for a pre-determined time period (holding time calculations are dependent on the number of scrap baskets in the MCO, ranging from 8 hr for no scrap baskets, to 20 hr for one scrap basket, to 28 hr for two scrap baskets).

3.4.2 MCO Backfill Gas

3.4.2.1 Gas Composition

MCO backfill gas will be provided by CVD systems and procedures in accordance with OCRWM requirements on the helium back fill gas per Irwin (1998). Oxygen concentration control is used to prevent formation of deflagrable gas mixtures after drying The gas overpressure provided after drying precludes air in-leakage during storage and establishes initial conditions consistent with the analysis of the MCO gas composition change during storage.

3.4.2.1.1 Added Gas

Helium is used as the inert gas added to the MCO void space.

3.4.2.1.2 MCO Void Gas

The MCO undergoes a series of process steps that evacuate and flow helium through the MCO. Therefore, the resulting void gas composition is not significantly different from the added gas.

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 to meet the requirements of Smith 1998 using ANSI N 14.5 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 0.5 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 Mechanically Sealed MCO Storage at CSB

The time a mechanically sealed MCO is stored in the CSB will be controlled administratively.

3.6.2 Leakage Rate After Welding

Leakage testing of MCOs shall be performed with CSB systems to meet the requirements of Smith 1998 and ANSI N 14.5 prior to placement in long term storage at the CSB.

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 Wall Temperature

MCO wall 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.

3.7 MCO Interim Storage

Some type of action to remove fuel from interim storage, or extend the storage system design life, must be defined and completed prior to the end of the facility and package design life.

4.0 TECHNICAL BASES

This section describes the technical bases for each process specification listed in Section 2.0.

4.1 Fuel Retrieval and Cleaning

The Fuel Retrieval System (FRS) is responsible for retrieving fuel from storage locations, cleaning it and placing it in fuel and scrap baskets. The fuel cleaning and basket loading activities performed by the FRS establish process parameters for all subsequent process systems. Fuel cleaning separates corrosion products from the fuel bearing materials loaded in fuel and scrap baskets. The criteria for this separation is consistent with the analysis of a bounding particulate inventory in a MCO which supports quantifying the inventory of material at risk for dispersion during accidents and the inventory of material containing hydration water. Basket loading specifications are consistent with analyses bounding the reacting surface area in a MCO, while basket queuing specifications are consistent with analyses of particulate generation on fuel in baskets after cleaning.

4.1.1 Fuel Cleaning

Fuel cleaning performance is based on the bounding particulate analysis in Sloughter, 1998. The analysis quantifies the bounding particulate inventory in a MCO by considering potential locations for residual particulate based on fuel characterization observations. These observations resulted in characterizing the components of residual particulate associated with fuel assemblies and scrap as: cladding films (composed of either uranium or aluminum compounds), an oxide film on exposed uranium surfaces, adhering particulate trapped in cracks within elements, and canister particulate (corrosion products accumulating in canisters that may collect in element flow channels).

4.1.1.1 Films and Adhering Particulate

The bounding particulate inventory analysis in Sloughter, 1998 is based on bounding quantities of films and adhering particulate as found in the basin with no intentional cleaning. Therefore, the FRS cleaning machine is not required to remove films or adhering particulate.

4.1.1.2 Canister Particulate

The bounding particulate inventory analysis in Sloughter, 1998 is based on satisfying cleaning criteria for separating canister particulate from fuel elements in the fuel cleaning machine. The overall approach is based on process validation outlined in Shen, 1997, where the process performance is demonstrated for a set of cleaning machine operating parameters during startup testing. Sloughter, 1998 includes an allocation for the residual canister particulate in a MCO that defines the process validation cleaning criteria.

The cleaning criteria is based on defining the quantity of canister particulate observed in flow channels that cause an assembly to be considered inadequately cleaned. The definition of an assembly that fails the cleaning criteria is as follows:

> An assembly fails the cleaning criteria if, when removing the inner element from the outer element, a quantity of corrosion product is observed to fall out of the assembly to form the equivalent of a circular pile 1 inch in diameter.

This criterion is actually applied only to elements that are being separated during the process validation test.

The fuel cleaning validation test is analyzed based on a pass/fail criterion for a canister, while cleaning is evaluated based on observation of individual assemblies. The assembly cleaning criterion is translated into the following pass/fail criteria for a test lot of canisters processed during the process validation test.

- If one assembly in a canister fails the assembly cleaning criteria, then the canister fails the canister cleaning criteria and there can be no more than one more assembly in canisters remaining in the test lot that fails the assembly cleaning criteria.

- If two assemblies in a canister fail the assembly cleaning criteria, then the canister fails the canister cleaning criteria and no more assemblies in canisters remaining in the test lot can fail the assembly cleaning criteria.

- If three assemblies in the canister test lot fail the assembly cleaning criteria, then the process validation test fails. If this occurs, the cleaning machine operating parameters must be revised and the validation test repeated.

Operation of the cleaning machine for loading fuel and scrap baskets can not begin until the process validation test is successfully completed.

The allocation for residual canister particulate in the bounding particulate inventory in Sloughter, 1998 is based on providing a 99% confidence that no more than 15% of the canisters will fail the canister cleaning criteria after passing the process validation test. A process validation test lot size of 29 canisters, combined with the criteria described above, is required to demonstrate this fuel assembly cleaning performance.

4.1.2 Scrap Basket Loading

4.1.2.1 Material with dimension < ¼ inch

Basket loading by the FRS must minimize the loading of scrap with dimensions smaller than ¼ inch to produce loadings consistent with analysis of the bounding reacting surface area developed in Ball and Duncan, 1998. Consideration of scrap pieces smaller than ¼ inch are excluded from the bounding surface area analysis. 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 (irradiated materials which may leave the MCO at the CVDF are evaluated in Sherrell, 1998a). High concentrations of reactive surface area in an MCO would exceed the basis of the thermal calculations that support safety analyses in subsequent processing systems (Plys and Duncan, 1998).

4.1.2.2 Scrap $<$ 1 inch and $\geq$ ¼ inch

Scrap sized from ¼ inch to 1 inch is to be loaded only in the fine scrap region of the basket to produce loadings consistent with the bounding reacting surface area developed in Ball and Duncan, 1998. This requirement ensures that the safety margin estimated in thermal calculations for subsequent process steps 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 and limiting the maximum distance between small scrap pieces and a highly conductive fin within the scrap basket.

4.1.2.3 Scrap $>$ 1 inch

The only limitations on larger pieces of scrap will be placement in the scrap basket, volume, and criticality mass limits imposed for handling baskets in the basin. This produces loadings consistent with the bounding reacting surface area developed in Ball and Duncan, 1998.

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). FRS will load fuel and scrap such as not to preclude normal loading of baskets into the MCO.

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 (consistent with the particulate generation analysis in Sherrell, 1998b). 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 (1998) 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.

The impact of a 30 day fuel queuing time was evaluated based on processing a MCO with bounding reacting surface area, while most MCOs will have surface areas well below the bound. Therefore, exceeding the fuel queuing time for all, or a portion of the fuel loaded in a MCO by a few days does not necessarily require recleaning of fuel. If fuel queuing exceeds 30 days, the actual storage time impact on particulate and hydration formation could be evaluated based on the actual condition of the stored fuel and compared to the bound on particulate generation and water inventory. 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 processed by a special procedure that is developed for the specific event causing delays, or 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

The bounding surface area analysis in Ball and Duncan, 1998 and thermal analyses of subsequent process steps limits the MCO loading to two scrap baskets.

4.2.2 Position of Basket of Scrap

Criticality analyses (Schwenkendorf, 1997) and thermal analyses of process steps (Plys and Duncan, 1998) are based on loading configurations where scrap baskets are located in either (or both) end of a MCO.

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. Basket loading procedures include the use of a guide to minimize the potential for particulate accumulations on MCO sealing surfaces. Shield plug installation includes a cleaining step to further reduce the potential for observing an inadequate seal.

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 Composition

4.3.1.1 Added Gas

Helium was selected as the MCO/cask inerting gas consistent with the gas used throughout the CVD process.

4.3.1.2 Package Void Space 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 the accumulation of flammable mixtures of hydrogen and oxygen from forming while the MCO is in transport between the K Basins and the CVDF. Flammable gas mixtures are precluded by reducing the void space oxygen concentration to less than 2.5 vol % prior to shipping (Edwards, 1998). A process specification of less than 2 % oxygen was selected as a conservative operating gas composition within the SARP requirements. 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 1998).

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 1998). A maximum pressure of 20.7 kPa, gauge (3 psig) is specified in Edwards (1998).

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 to be approximately 10 cm (4 inches) below the bottom of the shield plug, while the water level in the cask cavity is to be at the same level, which is 41.4 cm (16.3 inches) below the top of the cask lid. 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 1998).

4.3.4 Transport Between Loading and CVD

The SARP (Edwards 1998) limits the transfer time between the K Basins and the CVDF to 24 hours. Mitigation actions specified in Edwards (1998) must be implemented if transfer times exceed this limit.

4.4 Cold Vacuum Drying

The CVD Facility removes free water from the MCO allowing transport to the CSB and storage there for up to 40 years.

4.4.1 MCO Free Water Inventory

The inventory of free water in an MCO after drying (200 g) has been allocated based on the feasibility of identifying tests or procedures that confirm compliance with the specified limit (Pajunen 1998a). This allocation has been used as the basis for evaluating MCO pressurization and gas compositions during storage. Therefore, any future modification of this limit requires re-analysis of the stored MCO pressure and gas composition (see Frederickson and Plys, 1998). Section 4.6.3.3.7 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 Composition

4.4.2.1.1 Added Gas

Helium is to be used as 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 (Plys and Duncan 1998), which assume a helium backfill gas, have been used as the basis for gas temperature defining the molar gas inventory during storage (see Section 4.6.3.2). Therefore, helium must be used as a backfill gas for 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 (1998).

4.4.2.1.2 MCO Void Gas

The MCO void space gas composition oxygen content must be less than 2.5% to satisfy transportation criteria specified in Edwards (1998). However, this criterion is not limiting.

Hydrogen can be generated in a stored MCO after drying by residual water radiolysis or corrosion of uranium metal. Therefore, control of the MCO void space oxygen concentration was selected to preclude development of a deflagrable gas mixture in a MCO. Analyses of the MCO internal gas composition, investigating the transient oxygen composition of gas in MCO over a range of characteristics are performed in Frederickson and Plys (1998). This analysis, demonstrating that formation of a deflagrable gas mixture is precluded over the 40 yr storage period in the CSB, are based on an initial gas composition of 99.9% helium. Therefore, the MCO void space gas composition is specified as 99.9% helium to be consistent with the gas composition analysis.

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 (1998a).

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 (5.8 psig) 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 1998a). The maximum backfill pressure of 60 kPa, gage (8.7 psig) 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 fuel containment or confinement is required throughout processing. Smith, 1998 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 storage prior to welding 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^{-5} std cc/sec (Sherrell 1998a). This gaseous leakage rate is based on a clean seal and a clean sealing surface at the final mechanical closure boundary (Smith 1998). The mechanical seal leakage rate specification supports precluding development of flammable gas mixtures during transport and CSB storage prior to seal welding, as indicated in Sections 4.5 and 4.6.1.

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 a suitable environment for the MCO during transport and storage. The annulus region (between Cask and MCO) is used for controlled heating and cooling with tempered water during processing at the CVD Facility. The annular region is dried prior to transporting an MCO to the CSB. The dew point of a 0.5 vol % water vapor-gas mixture is approximately -2°C. Edwards 1998 evaluates minimum component temperatures for a normal 14 hr transfer assuming no solar, radiolytic or chemical heat during worst case low environment temperatures of –33 °C (-27 °F). Under these conditions, the MCO exterior and cask interior surface temperatures range from –2 °C to 44 °C. Therefore, limiting the water vapor content of the annular space to less than 0.5 vol % precludes the presence of liquid water on the

MCO exterior and cask internal surfaces if the cask temperature does not decrease below -2°C (28°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

Thermal analyses indicate that the cask lid temperature on receipt at the CSB, after a normal transfer time period under hot day conditions, will be bounded at 40°C (104°F) for an initial shipping temperature of 25°C (77°F) [refer to Figure B8-10 of Edwards 1998]. This temperature is considered low enough for operator handling activities in the CSB receiving area and represents the basis for specifying a cask temperature of less than 25°C prior to shipping. Actual cask lid temperatures are dependent on the transport time period and may exceed 40 °C if the transport were delayed on the road for an extended time period.

4.4.5 Halogenated and/or Organic Compounds

Smith (1998) describes the corrosion conditions used as a basis for design of the MCO. When flooded with water, the MCO design corrosion considerations are based on water with chloride ion concentrations less than 1 ppm and fluoride ion concentrations less than 0.25 ppm. Once drained, the MCO design corrosion considerations are based on preventing the generation of a moist halide gas within the MCO. Halogenated compounds have the potential to produce a halide gas by radiolysis. Therefore, introduction of halogenated compounds into the MCO must be prevented to comply with design assumptions. Oils and other organic compounds have the potential to produce complex radiolysis products that are not addressed in the analysis of MCO pressurization and gas composition during storage. Therefore, the introduction of halogenated or organics into an MCO shall be precluded throughout the life cycle of the MCO. This is also an OCRWM requirement for the CVD Facility per Irwin (1998).

4.5 Cask Transport to CSB

Upon completion of cold vacuum drying, the MCO and Cask are prepared for transport to the CSB. Edwards (1998) evaluates hydrogen leakage from an MCO assuming the MCO mechanical seal leak rate is established to be $< 1 \times 10^{-5}$ std cc/sec as specified in Section 4.4.2.4. Based on the analysis in Edwards (1998), the most restrictive time limit

(< 234 hr) results from the requirement to maintain the hydrogen concentration around a bounding case MCO below the 2.5 vol%. Mitigation actions must be implemented if transfer times exceed 234 hr (9.75 days).

4.6 Canister Storage Building Systems

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

4.6.1 Mechanically Sealed MCO Storage at CSB

The mechanically sealed MCO storage 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 (1998a) evaluates helium leak rates from an MCO for single occupancy tubes (i.e., only one MCO with a mechanical seal is allowed per tube) assuming the MCO mechanical seal leak rate is less than 1×10^{-5} std cc/sec, as specified in Section 4.4.2.4. Based on the analysis in Sherrell 1998a, and the minimum helium backfill addition specified in Section 4.4.2.3, the time between checking the MCOs and tubes must be limited to less than 3 ½ years in order to maintain a positive pressure within a MCO under extreme low storage temperature conditions and not reach the 4 vol% H_2 concentrations in the tubes.

4.6.2 Leakage Rate After Welding

The MCO, when sealed by welding at the CSB weld station, shall be capable of not exceeding a maximum total leak rate of 1×10^{-7} scc/sec (Smith 1998). Flammable gas management evaluations in Sherrell 1998a indicate that multiple ("dozens") weld penetrations, each with a leakage rate of 1×10^{-7} scc/sec, can be accepted while maintaining control of the flammable gas concentrations in a storage tube. Individual MCO components are tested against the leakage rate specifications of 1×10^{-7} scc/sec. Therefore, a composite package leak rate of less than 3×10^{-7} scc/sec is specified based on each of the following components: (1) MCO shell assembly, (2) MCO cover cap assembly, and (3) joining seal weld satisfying the leak rate test.

4.6.3 Sealed Storage Condition

4.6.3.1 MCO Maximum Internal Pressure

The MCO maximum internal pressure, with welded cover cap installed, is limited to 450 psig, or 465 psia (3.2 Mpa), consistent with the design pressure in Smith 1998.

4.6.3.2 MCO Wall Temperature

The CSB design is based on limiting the MCO wall temperature for a bounding heat load to 270°F (132°C) during storage (Swenson 1996). The maximum MCO wall

temperature determines the temperature of gases inside the MCO, which influences the gas pressure during storage in the CSB based on the ideal gas law. Thermal analyses of interim storage in Plys and Duncan (1998) and Frederickson and Plys (1998) indicate the maximum projected MCO wall temperature is expected to be bounded by 108°C, with a corresponding maximum fuel temperature of 130°C.

An upper bound on the MCO gas temperature can be estimated from the maximum wall temperature by assuming conduction is the primary heat transfer mechanism and the maximum gas temperature is defined by the maximum fuel temperature. This conservative approach results in an estimate of 154°C for the maximum gas temperature based on the fuel to wall temperature difference and maximum MCO wall temperature.

4.6.3.3 Water and Gas Inventory in MCO

The total water inventory after drying determines the worst case projected internal pressure within the MCO. The maximum water inventory during storage is derived from a combination of bounding analyses defining the hydration water inventory and the free water removal criteria described in Section 4.4.1. Other identified gas generation mechanisms in a MCO are evaluated and the sum of gases compared to the total gas inventory defined by the maximum pressure and temperature. The difference between identified sources and total gas limit represents the MCO design conservatism. Table 4-1 summarizes the total gas and contributors identified by other mechanisms. 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 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.

$$Gas\ quantity = \frac{PV}{RT} = \frac{\left(\frac{465\ psia}{14.7 psia/atm}\right)(500\ L)}{\left(0.082\ \frac{atm\text{-}L}{gmol\text{-}K}\right)(273 + 154\ K)} = 452\ gmol$$

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

Constituent	Gas in multi-canister overpack, gmol	Explanation
Total gas	452	Maximum pressure of 465 psia (3.2 Mpa [abs]) at 309°F (154°C) gas temperature with a 500 L gas volume.
Backfill gas	32.7	The MCO will be initially filled with helium to a positive gage pressure not to exceed 23.5 psia at 77°F (25°C).
Noble gases (Kr, Xe)	< 0.2	Fission product noble gases released as a result of corrosion of the fuel, based on a water inventory of 5,000 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	13.3	Oxygen concentration not to exceed 4 vol. % to preclude flammable gas mixtures.
Total water and hydrogen	301	See Section 4.6.3.3.7
Unallocated	104.7	Difference between total allowable gas and sum of identified constituents. Currently identified constituents result in MCO approaching within 75% of design pressure.

4.6.3.3.2 Unallocated Gas Inventory

The unallocated gas inventory represents the margin available accommodate uncertainties in the addition of trace materials not specifically considered as a contributor to MCO pressure. Trace quantities of organic materials, as small pieces of debries that can not be distinguished from scrap, represent the primary loading uncertainty. Gaseous products produced by organic material radiolysis can add to the internal pressure of the MCO.

Table 4-1 indicates the unallocated gas inventory in a MCO is approximately 100 gmol, assuming bounding values from other constituents. This quantity of gas could be generated by completely decomposing 100 gmol of CH_2 fractions from organic molecules. This would represent a minimum of 1.6 kg trace organics added to the MCO, or a minimum volume of approximately 1 L. This volume of organic material would represent a significant fraction of the fines section volume of a scrap basket (approximately 17 L). Therefore, the volume of organic material added to a MCO would need to be an observable quantity in order to approach the available pressure margin.

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 margin between bounding and design pressures within a MCO. 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 margin available between bounding and design pressure is maintained.

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. Praga (1998) 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 5,000 g (278 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 278 gmol of water is approximately 139 gmol U, or 33 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 0.18 gmol Kr+Xe, or less than 0.2 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. Praga (1998) does not contain estimates of trace 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 at 33 kg of uranium reacted. Based on a molecular weight of 4 g/gmol for helium, the helium gas release by metal corrosion is then estimated at 0.002 gmol He, or 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 result in pressurization of an MCO (Frederickson and Plys, 1998). Oxygen gettering by uranium metal is projected to maintain oxygen concentrations at less than 4% in an MCO for all potential combinations of MCO loadings and decay heat. An allocation of 4% of the backfill gas plus hydrogen 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 [301 + 32.7]) = 13.3 gmol of gas for oxygen.

4.6.3.3.7 Water and Hydrogen

As indicated above, water reacts with uranium metal to form an oxide layer and release hydrogen gas. In addition, radiolytic decomposition of water will also occur, producing hydrogen and oxygen gases. As the temperature in the MCO increases, volatilization of water also will increase. Water must be controlled to limit the pressure in the MCO and the buildup of hydrogen.

Duncan and Ball (1998) summarize maximum estimates for the bound water content of solids (fuel particulate and fuel coatings) in an MCO. While free water removal is expected to be complete, configurations can by hypothesized where water is trapped in fuel pockets or cracks. An allocation of 200 g free water has been included in the consideration of total water inventory based on satisfying the criterion in Section 4.4.1. Therefore, the MCO water inventory after drying is not directly measured, but derived from a combination of analyses and process procedures that allow one to conclude the water inventory is bounded. The following list summarizes maximum estimates for the MCO bound and free water inventory from Duncan and Ball (1998).

-	Water in cladding film	3.315 kg
-	Water in oxide film, scrap	0.063 kg
-	Water in adhering particulate	1.036 kg
-	Water in canister particulate	0.144 kg
-	Water in generated particulate	0.083 kg
	Total water in particulate	4.641 kg
-	Residual free water after drying	0.200 kg
	Total water in MCO	4.841 kg

The water inventory above is based on a MCO containing two scrap baskets. This represents the maximum total water inventory estimated for a MCO.

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

Pajunen (1998b) provides a bounding estimate of 5.13 kg UH_3 after drying for a MCO containing two scrap baskets. This corresponds to an inventory of 21.3 gmol UH3 (5130/241) which can react with water by the above stoichiometry to form 72.6 gmol H_2 while consuming 42.6 gmol water. The total water inventory is bounded by 269 gmol (4841/18) listed above. Therefore, the maximum hydrogen production, independent of rate considerations can be found by assuming all uranium hydride reacts to form water and the remaining water reacts with uranium metal. This results in a hydrogen production estimate of 301 gmol (269 – 42.6 + 72.6).

4.7 MCO Interim Storage

The MCO structure and components, as well as CSB systems, are designed for a 40 year life (Smith 1998 and Swenson 1996) based on storing two sealed MCOs per storage tube.

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.

5.0 REFERENCES

ANSI, 1987, *American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment*, ANSI N14.5-1987, ANSI, New York, New York.

ASME Code, Section III, Division 1, Subsection NB, 1995 Edition with 1995 Addenda.

Ball, D. E. and D. R. Duncan, 1998, *Fuel Surface Area*, HNF-SD-SNF-CN-017, Rev. 3, DE & S Hanford, Inc., Richland, Washington.

Duncan , D. R. and D. E. Ball, 1997, *K-Basins Sludge Water Content Behavior, and Impact*, HNF-1523, Rev. 1, DE & S Hanford, Inc., Richland, Washington.

Edwards, W. S., 1998, *Safety Analysis Report for Packaging (On-Site) Multi-Canister Overpack Cask*, HNF-SD-TP-SARP-017, Rev 1, Waste Management Federal Services, Inc., Richland, Washington.

Frederickson, J. R., and M. G. Plys, 1998, MCO Internal Gas Composition and Pressure During Interim Storage, HNF-SD-SNF-TI-040, Rev 1, DE&S Hanford, Richland, Washington.

Heard, F. J., 1996, *Thermal Hydraulic Feasibility Assessment for the Spent Nuclear Fuel Project*, WHC-SD-WM-ER-525, Westinghouse Hanford Company, Richland, Washington.

H-2-828041, Rev. 0, *Multi-Canister Overpack Assembly*.

H-2-828070, Rev. 0, *MCO Mark IV SNF Storage Basket*.

Irwin, J. J., 1998, *Cold Vacuum Drying Facility Design Requirements*, HNF-SD-SNF-DRD-002, Rev 3A, Numatec Hanford Co., Richland, Washington.

Pajunen, A. L., 1998a, *Cold Vacuum Drying Residual Free Water Test Description*, HNF-1851, Rev. 2, COGEMA Engineering Corporation, Richland, Washington.

Pajunen, A. L., 1998b, *Uranium Hydride in Multi-Canister Overpacks*, HNF-3372, Rev. 0, COGEMA Engineering Corporation, Richland, Washington.

Plys, M. G., and D. R. Duncan, 1998, *Simulation of Normal and Off-Normal Multi-Canister Overpack Behavior*, HNF-2256, Rev 2, DE&S Hanford, Richland, Washington.

Praga, A. N., 1998, *105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Activities, Volume 1, Fuel*, HNF-SD-SNF-TI-009, Volume 1, Rev 2, DE&S Hanford, Richland, Washington.

Schwarz, R. A., 1997, *Modification to ORIGEN2 for Generating N Reactor Source Terms*, PNNL-11555, Pacific Northwest National Laboratory, Richland, Washington.

Schenkendorf, K. N., 1997, *Criticality Safety Evaluation Report for Spent Nuclear Fuel Processing and Storage Facilities*, HNF-SD-SNF-CSER-005, Rev 3, Fluor Daniel Northwest, Richland, Washington

Shen, E. J., 1997, *Fuel Retrieval System Process Validation Plan*, HNF-SD-SNF-PAP-003, Rev. 0, DE & S Hanford, Inc., Richland, Washington.

Sherrell, D. L., 1998a, *Multi-Canister Overpack Combustible Gas Management Leak Test Acceptance Criteria*, HNF-2155, DE&S Hanford, Inc., Richland, Washington.

Sherrell, D. L., 1998b, *Radionuclide Inventory of Bulk MCO Water at the Cold Vacuum Drying Facility*, HNF-SD-W441-CN-001, Rev. 2, DE&S Hanford, Inc., Richland, Washington.

Sloughter, J. P., 1998, *Estimates of Particulate Mass in Multi-Canister Overpacks*, HNF-1527, Rev. 1, Numatec Hanford Corp., Richland, Washington.

Smith, K. E., 1998, *Performance Specification for the Spent Nuclear Fuel Multi-Canister Overpack*, HNF-S-0426, Rev. 4, DE & S Hanford, Inc., Richland, Washington.

Swenson, C. E., 1996, *Performance Specification for the Spent Nuclear Fuel Canister Storage Building*, WHC-S-0425, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

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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	X3-72	X			
J. E. Turnbaugh	X3-79	X			
Fluor Daniel Hanford					
E. W. Gerber	R3-11	X			
R. L. McCormack	R3-11	X			
M. J. Wiemers	R3-11	X			
Fluor Daniel Northwest					
L. J. Garvin	R3-26	X			
Numatec Hanford Corp.					
G. D. Bazinet	S8-06	X			
T. Choho	R3-86	X			
J. J. Irwin	R3-86	X			
C. R. Miska	R3-86	X			
J. P. Sloughter	H0-34	X			
COGEMA Engineering					
M. J. Klem	R3-86	X			
A. L. Pajunen	R3-86	X			

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D. C. Bryson	S7-41	X
R. M. Hiegel	S7-51	X
C. B. Loftis	S7-51	X
P. G. Loscoe	S7-41	X
K. M. Schierman	S7-41	X
G. D. Trenchard	S7-41	X

R3-11 X

SNF-Jeke

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